10 Saturn discoveries from the Cassini mission p. 30

Easter Island eclipse images p. 52

November 2010

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The Kepler spacecraft's search for other worlds

Johannes Kepler decoded how the Sun's planets move. Now his namesake mission hunts for other planetary systems. p. 22

The Kepler mission is on the hunt for extrasolar planets. Astronomers expect the spacecraft to discover everything from gas giants close to their suns to Earth-sized planets in habitable zones.

The world's biggest telescopes illustrated p. 28

Tour the Local Group of galaxies p. 46

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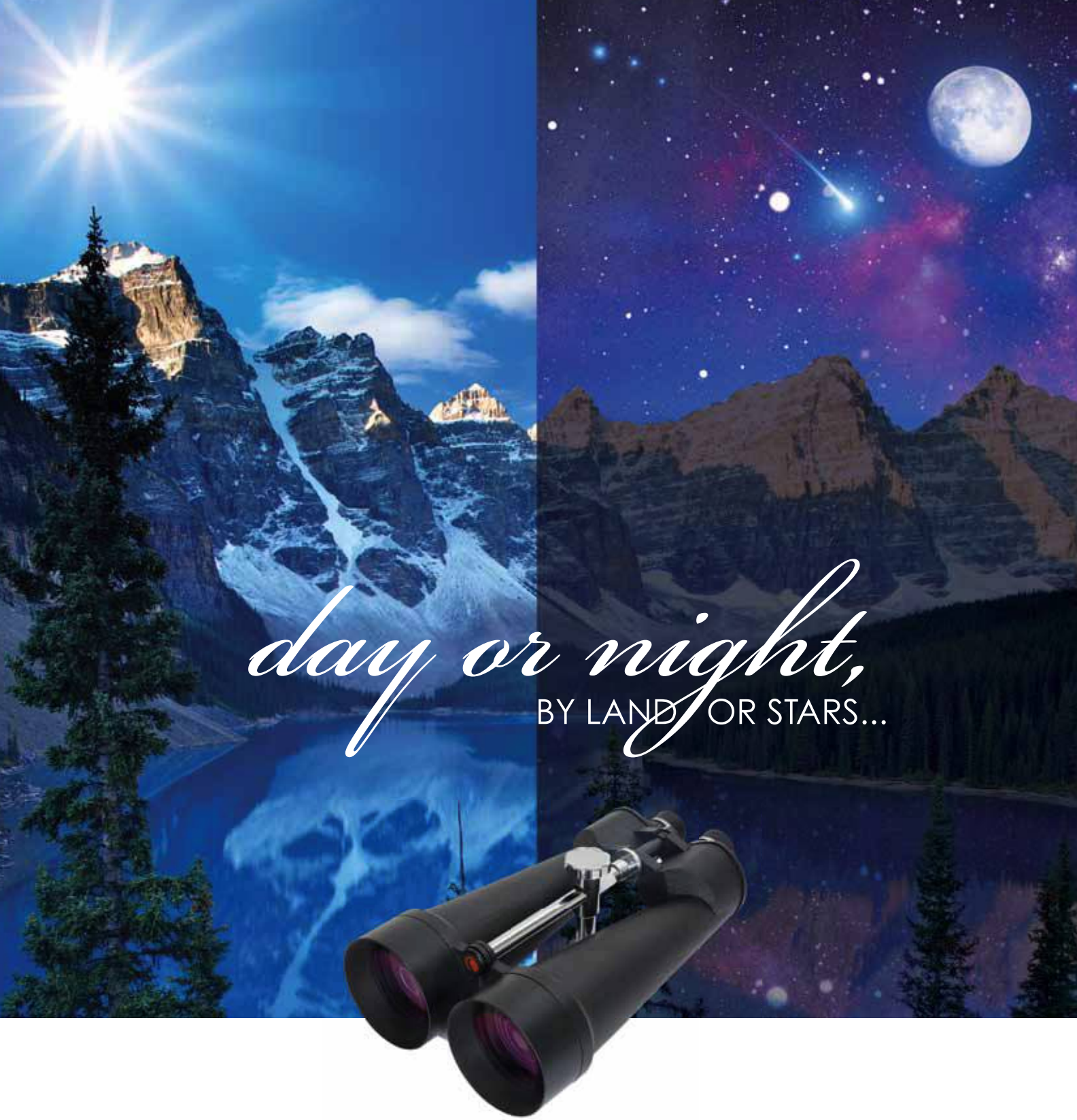

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AT65EDQ image by Jason Blaschka.

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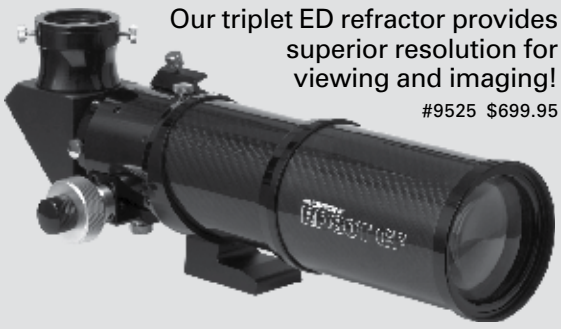

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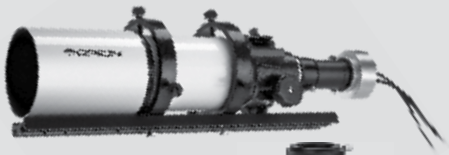

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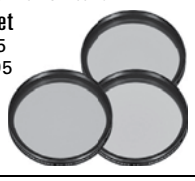

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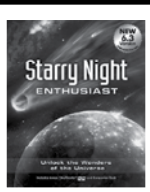

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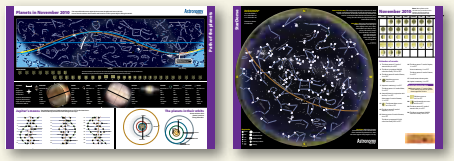

Path of the planets and StarDome.

10 Saturn discoveries from the Cassini mission
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The Kepler spacecraft's search for other worlds
The world's biggest telescopes illustrated
Tour the Local Group of galaxies

Cover: Lynette Cook for *Astronomy*

ON THE COVER

The Kepler spacecraft launched March 2009 and is currently surveying some 170,000 stars. That information likely hides hints of hundreds of extra-solar planets.

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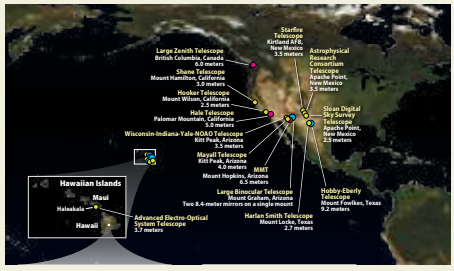

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A revolutionary observing opportunity

by David J. Eicher

As amateur astronomers, we spend most of our lives away from dark skies. A new concept in observing is about to change all that, however, and will make access to a dark sky easier and more affordable than ever.

Astronomy promoter and developer Gene Turner is unveiling Granite Gap, his latest mecca for amateur astronomy. Before this, Turner also created Arizona Sky Village and Rancho Hidalgo. This time, Turner is offering low-cost land for RV owners, for those who simply want an observatory they can operate robotically, or for those who want to purchase an inexpensive, small, furnished cabin with their scope beside it. The cost is amazingly low — a one-time fee of $2,500 will lease a one-third acre plot for 99 years, which includes a telescope pad, electricity, water, septic, and high-speed Internet. Cell phone service also works nicely. The site is located north of Animas, New Mexico.

Beautiful vistas of the Chihuahuan Desert will accommodate many observatory sites at Gene Turner's Granite Gap development. David J. Eicher

Granite Gap has the possibility of becoming a unique gathering place for astronomy enthusiasts. As I stood under the summer Milky Way, I was amazed. The sky is world-class dark with a "three-dimensional" Milky Way etched with dark lanes and bright naked-eye visibility of many Messier objects. The telescopic views are fantastic — we saw bright objects like the Lagoon, Trifid, and Omega nebulae.

Turner's plans include a large lake for fishing and recreation. He also will start a planetarium and mineral and meteorite museum. Archeology is a big part of the area, as well. Nearby Native American sites include cave pictographs. Mining history and lore are staples of the area, too, and Turner owns several defunct mines that he will open for education. Also, there are plans to add a golf course in the future.

With the endorsement of planetary scientist Carolyn Shoemaker, Turner is putting together Shoemaker Discovery Park, which will feature big-scale model rocketry, a simulated impact crater to explore, and other features that will pay tribute to Carolyn's late husband, Gene Shoemaker. In 1993, Shoemaker, along with his wife and *Astronomy* Contributing Editor David H. Levy, co-discovered Comet Shoemaker-Levy 9.

For more on this remarkable venture, visit www.granitegap.com.

For a background story by Senior Editor Michael Bakich that appeared in the September 2010 issue of *Astronomy*, see www.Astronomy.com/NewMexico. Also, see www.Astronomy.com/observing for my blog about Granite Gap.

Stay tuned for more reports on this development, which promises to deliver what we all dream about — a supremely dark sky in a reasonably easy way.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 38, Number 11

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Where are we?

As a longtime *Astronomy* magazine subscriber, I was amused by the picture of the 3.5-month-old "new recruit" in the Letters section of your July 2010 issue. I look forward to a new issue every month, and the included picture proves that this magazine appeals not just to the animate among us. Keep up the great work. **— Tim Sisk,** Bismarck, North Dakota

***Astronomy* magazine shows up all over, including in the hands of this stuffed monkey. Where will we find it next?** Tim Sisk

This letter and included photograph made the staff think, "We could turn this image into an entire section!" The result is a new area in our Online Reader Gallery, "Where in the World is Astronomy*?" We want readers to share pictures of the magazine in different cities around the world and/or in unusual settings. So, take the most recent issue of* Astronomy *with you on your next trip, snap some pictures at interesting locales, and upload them to www.Astronomy.com/readergallery. We're excited to see all the places the magazine ends up.* **— Karri Ferron,** Copy Editor

A positive inspiration

I enjoyed reading the article about Bart Bok and the Bok Telescope ("A famous telescope turns 40") in your July 2010 issue. I believe Bok would be most pleased with the University of Arizona's astronomy camps and, specifically, the efforts of Don McCarthy, astronomer at the university and director of the camps. Through McCarthy's leadership, the camps have produced many scientists, engineers, and astronomy enthusiasts. I'd guess that the teens who have come through his camp over the past 20+ years have made many contributions in their respective fields.

McCarthy has made, and continues to make, scholarships available to children with a strong desire to participate who might not otherwise have been able to. To paraphrase Captain Picard from *Star Trek: The Next Generation*, McCarthy "makes it so," and he ensures every penny of the tuition counts.

Having attended many of his camps as an adult camper and as a counselor for the young teen camps, I know what a wonderful experience these programs offer. These camps inspired me, which is one of the reasons I am a Solar System Ambassador volunteer for JPL/NASA.

I never knew Bart Bok personally, but with all that he accomplished during his lifetime, I believe he is looking down from the heavens with a large smile on his face! **— Janet S. Howard,** Bartlett, Tennessee

Rethink cosmic time

Please stop referring to "a few hundred million years" as a "blink of an eye in cosmic time." If the universe is 13.7 billion years old, then 200 million years is about 1.5 percent of the elapsed time. This percentage on a human scale of, say, 65 years is equivalent to about 350 days — I wouldn't call that a blink. Thanks for your consideration. **— Clinton Ross,** Plymouth, Massachusetts

New astronomy enthusiast

Recently, I've had to give up all of my hobbies due to a physical disability — this included selling my motorbike. However, doing so allowed me to put that money into purchasing a new telescope, something I've always wanted. I am still waiting for it to arrive, but in the meantime I've been soaking up every bit of astronomy news and information I've come across.

I saw your magazine in the store the other day and purchased it on a whim. I have to admit, I was initially skeptical. In the age of instant and seemingly unlimited information on the Internet, was there really a need for a physical magazine? I am happy to be mistaken.

I read it cover to cover in almost one sitting! Aside from having tons of astronomy news and facts, I was surprised to find all kinds of hints, viewing times, and charts for next month. It wasn't mostly advertising like many other magazines; you have informative and substantive articles, and the advertising you do have is related to astronomy. I was so pleased with the magazine that my wife purchased a subscription for me as a Father's Day gift.

So, thank you for an amazing magazine. I look forward to the upcoming issues. **— Richard Bostock,** Meaford, Ontario, Canada

Corrections

The June 2010 Cosmic Grid (page 64) shows a sleeping bag referred to as the "Solo Sleeper" shaped like a Tauntaun. We incorrectly stated that Han Solo slept inside the Tauntaun in *The Empire Strikes Back*. He actually cut open the Tauntaun to keep Luke Skywalker warm while he erected a shelter. The editors deeply regret making such a blunder as we celebrate the film's 30th anniversary year.

In addition, we'd like to clear up a source of confusion from the July 2010 article "How sky surveys will revolutionize astronomy." While the full Pan-STARRS 4 survey is slotted to be on Mauna Kea when it's fully operational in 2013, the first telescope (PS1) is currently on Haleakala's summit on Maui. **— *Astronomy* Editors**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Web Talk

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What's new at Astronomy.com. **by Karri Ferron**

Featured video

Autumn observing targets for large telescopes

In this video, *Astronomy* magazine Editor David J. Eicher highlights the deep-sky objects you can see this fall using a large telescope. Targets include the Bubble Nebula (NGC 7635), the Pinwheel Galaxy (M33), Stephan's Quintet, and more! Check it out at www.Astronomy.com/videos.

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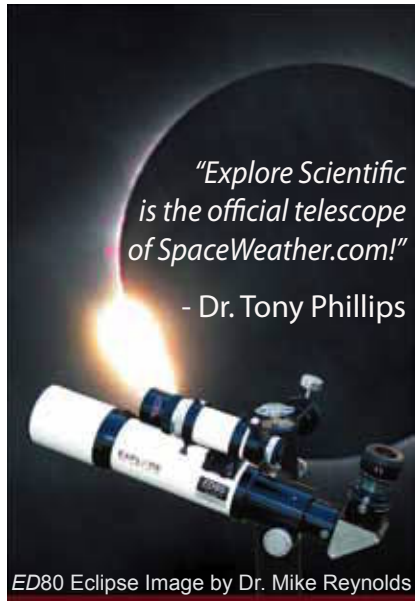

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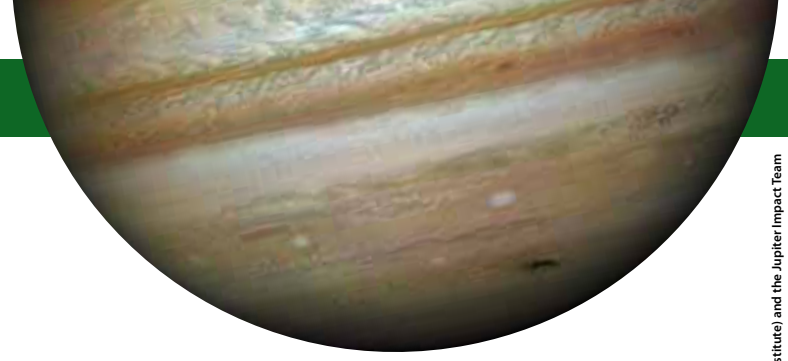
Strange**Universe**

by Bob Berman



NASA/ESA/ H. Hammel (Space Science Institute) and the Jupiter Impact Team

No jovial refund

Jupiter wins the title of the solar system's strangest planet.

In all these years of writing "Strange Universe," no planet has ever been the subject. Let's remedy that. But which planet is truly strangest?

If "strange" means "different," then every planet might qualify. Each enjoys at least one odd trait seen nowhere else. Yet Jupiter stands out in too many ways not to be crowned the winner.

The ancient Greeks and Romans somehow knew this, too. They hit the mark when they decided that Jove dominates the heavens despite Venus being brighter, and revered it as "king of the gods."

Right now, it rules the night. Jupiter is simply the brightest "star" in the sky, a lighthouse on the forlorn Aquarius-Pisces border. It loves those watery constellations: Jove lingered in Pisces earlier this year, retrograded into Aquarius in October, and now, doing an about-face, will re-enter Pisces in time for the holidays.

We've just begun a wonderful, long stretch when Jupiter walks the runway in primetime. It recently served 5 years "penance" slinking through the lowest zodiacal depths. Now and for the next 7 years, its nightly sky path carries it high above thick horizon air, permitting sharp imagery.

There's more. This year, Jupiter's oval orbit brings it nearer to us than at any time since John Kennedy was in the White House. It looks more than 10 percent larger — and thus shows more detail — than it did only a few years ago. After it ducks behind the Sun late this winter and then returns for its 2011 viewing window, it will look just as good.

But all this talk is like discussing the clear waters of the Caribbean. The only sensible thing is immersion, and here is where it pays to have a telescope.

Despite using a truly pathetic low-power instrument 4 centuries ago, Galileo peered at Jupiter and changed our view of the universe. Its four circling moons proved Earth is not the center of all motion. Of course, later on in 1633, he was forced to eat crow. On his knees, Galileo told the Inquisition that he was wrong about everything.

We can't blame him. I would have told those idiots whatever they wanted to hear too — just 33 years earlier they had burned poor Giordano Bruno at the stake for saying the universe is infinite.

Impress your friends. Identify those Galilean satellites by name. Innermost Io zips around Jupiter in just 1¾ days, visibly shifting during a 2-hour observing session. The next nearest, Europa, takes exactly twice as long and is a bit fainter. Ganymede, the solar system's largest moon, is clearly brighter than the others and revolves once a week. Such a simple 1:2:4 orbital relationship means the moons are gravitationally locked in sync like a marching band. Finally, Callisto, the faintest, is the only one that goes out more than 8 Jove-widths. Who needs a finder chart?

Jove's huge gravity sucks in any foolhardy comet or asteroid that ventures too close.

Weird stuff is everywhere. Jupiter's screaming-fast rotation around its metallic-hydrogen core generates big-time electricity, creating a larger magnetic field than the Sun's — the source of Jove's commercial-free radio broadcasts. Its equator whooshes crazily at 25,000 mph (40,000 km/h), 24 times faster than ours. Cloud bands rub violently against their neighbors. Lightning that dwarfs Earth's a thousandfold flashes continuously. Heat from the jovian core — the hottest place in our solar system outside the Sun — bakes the murky gases that rise up from below, while cold white clouds get pulled under. It's a carnival of ever-changing features.

Normally, two dark horizontal belts dominate the landscape. But earlier this year, one vanished, *poof*, for the first time in decades. Whenever this Southern Equatorial Belt gets skimpy, the Great Red Spot gets more striking, and it's now more spectacular than I've ever seen it. Steady conditions and a good scope also reveal white ovals, swirls, blue festoons — everything but the kitchen sink.

What makes all the colors? "We really don't know," the universally beloved planetary expert Carolyn Porco told me a couple of years ago. The Red Spot might come from sulfur compounds. Or it might be phosphine, a tasty blend of phosphorus and hydrogen. Jupiter is still mostly a mystery.

What we cannot see is the witch's brew of organic compounds lurking down below. When we mimic jovian lightning by passing electrical sparks through its known gases, every amino acid is created within a week. What might we find floating in Jupiter's dense, roughly room-temperature middle layers?

Meanwhile, Jove's huge gravitational influence, 318 times greater than our own, sucks in any foolhardy comet or asteroid that ventures too close. Some create dark scars. Is this variety of activity an astronomer's dream or what?

So Jupiter wins the strangest-world award. It's probably worth buying a telescope for this planet alone. Jove never disappoints, but in any case you can always return the instrument. Galileo had to pack up his eyepieces for fear of being burned at the stake. At most telescope stores, the refund policy is less intimidating.

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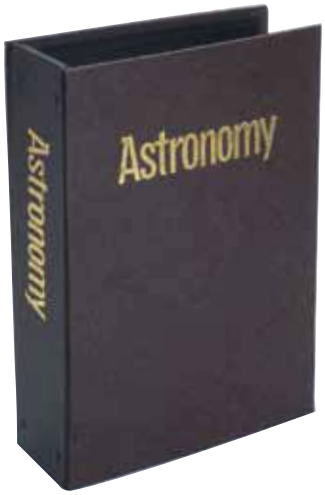

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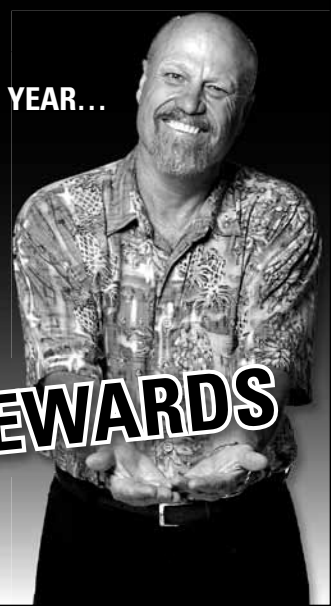

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by Stephen James O'Meara

Back from the dead

Jupiter's South Equatorial Belt practices its disappearing act once again.

Of all the planets available to small-telescope users, Jupiter is the most satisfying. It's also one of the most mysterious. Who hasn't gone to the eyepiece expecting to see the planet's dusky polar regions and two dark equatorial belts surrounded by bright zones? We like to rely on these features to be present, especially when showing Jupiter to the public. But the giant doesn't always comply.

In May 2010, after Jupiter passed behind the Sun and reappeared in the morning sky, observers noticed that one of its most prominent features, the South Equatorial Belt (SEB), had disappeared. The visually lopsided world even jolted seasoned observers. The event reminded me of two things: (1) how comfortable we feel with order and symmetry (for instance, the more symmetrical a face, the more beautiful we perceive it to be); and (2) how superficial Jupiter's face truly is.

Surprising as it might have been, the "demise" of the SEB was not unprecedented. It had been fading before conjunction, and veteran observers knew it was just a matter of time. Like all of Jupiter's belts and zones, the SEB is a fluid gas kept in line by both the planet's fast rotation and the extensive convection of internal heat rising to the surface. But, for some still unknown reason, every 15 to 20 years the SEB fades from view. One thing seems quite certain, however: The SEB will return. And when it does, be prepared for some visual violence!

SEB revivals

While the SEB can appear as a solid dark band, it also can appear as two pieces: a dark north component or band part (SEBn) and a dark south one (SEBs). The middle part of the belt can be either a soft, uniform shade of brown or bright and featureless, like a zone.

When the SEB vanishes, the middle part of the band fades first, followed by the southern part, and then the north. Sometimes the SEB's north and south edges don't disappear completely, but remain visible as thin, faded ribbons. At other times, the dark regions completely vanish, and the planet's southern hemisphere becomes home to a wide swath of whiteness.

Compared to the slow and tranquil "death" of the SEB, its revival can be fast and furious, suddenly and rapidly transforming the whole region into a swirling brew of visual discord.

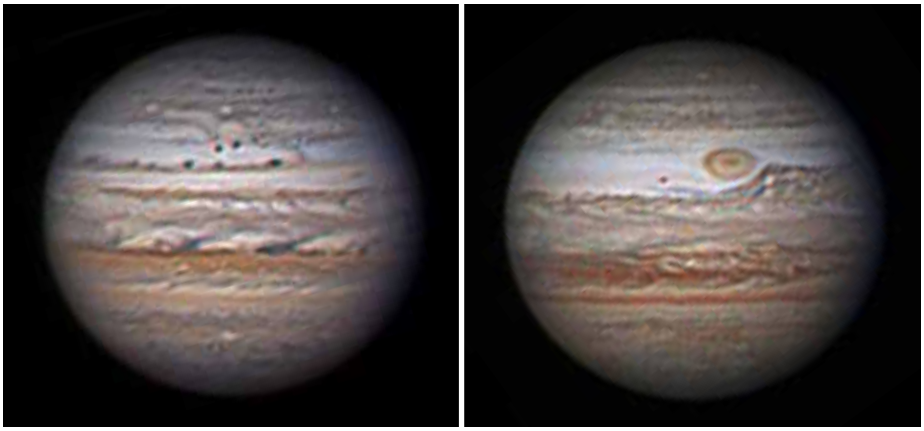
Detailed observations of SEB revivals began in January 1919 when the belt began to fade before vanishing altogether. It didn't stir back to life until December. By February 27, 1920, British observer Harold Thomson said, "The SEB is a most extraordinary spectacle. It consists largely of round dark dots and white spots." In his 1958 classic *The Planet Jupiter*, Bertrand M. Peek added, "Moreover, the changes of aspect were so rapid that it was almost impossible to identify the markings after so short an interval as a couple of days."

Throughout recorded history, SEB revivals have usually begun with a stationary dark spot or streak. (A bright spot may accompany, or appear prior to, the dark spot, but it's usually harder to notice against the bright background.) Darkness then returns to the belt, spreading from that stationary spot along three currents: westward along the SEBn (toward the preceding limb), eastward along the SEBs (toward the following limb), and westward along the middle of the belt.

Expect eruptions

The SEB does not simply reappear as growing lines of darkness but as multiple eruptions of discrete dark and bright spots, gray wisps, and dark bulges, all simultaneously occurring and drifting from the source along the three currents. The source can remain visible for weeks, but eventually it mingles with the chaos and becomes unidentifiable. Multiple outbreaks also can occur. In 1975, for instance, for the first time in recorded history, the SEB revived

Jupiter's South Equatorial Belt disappeared in May 2010, as it does every 15 to 20 years. Just why it does so remains a mystery, but there's no doubt that the belt will one day return. Christopher Go



The South Equatorial Belt's revival is typically a time of turbulence and upheaval in Jupiter's atmosphere, with multiple dark spots and dark bulges appearing suddenly, as seen above in the 2007 revival. (South points up in both pictures.) Don Parker

Browse the "Secret Sky" archive at www.Astronomy.com/OMeara.

Rather than waste time drawing all of Jupiter, the author here spent an hour surveying just a portion of the planet and sketching it in detail. Each drawing from left to right represents the passage of 20 minutes as seen through the Lick 36-inch refractor on August 9, 1995. (South points up in all sketches.) Stephen James O'Meara

from three principal sources of activity (all bright white clouds).

As of this writing, John Rogers, director of the British Astronomical Association's Jupiter Section, says that the SEB has almost completely disappeared and is now perceptible in images only as faint yellowish and bluish bands. "Meanwhile," Rogers says, "the Great Red Spot has intensified to become an isolated orange oval, surrounded by a bright white 'moat.' These changes began last year, and have proceeded as predicted."

The SEB last faded (but didn't vanish) as recently as 2007. But this year's event, Rogers says, has progressed much further so the belt has almost disappeared, as last seen in 1990 and 1993. These years (1990, 1993, 2007) were also the years of the most recent SEB revival outbreaks.

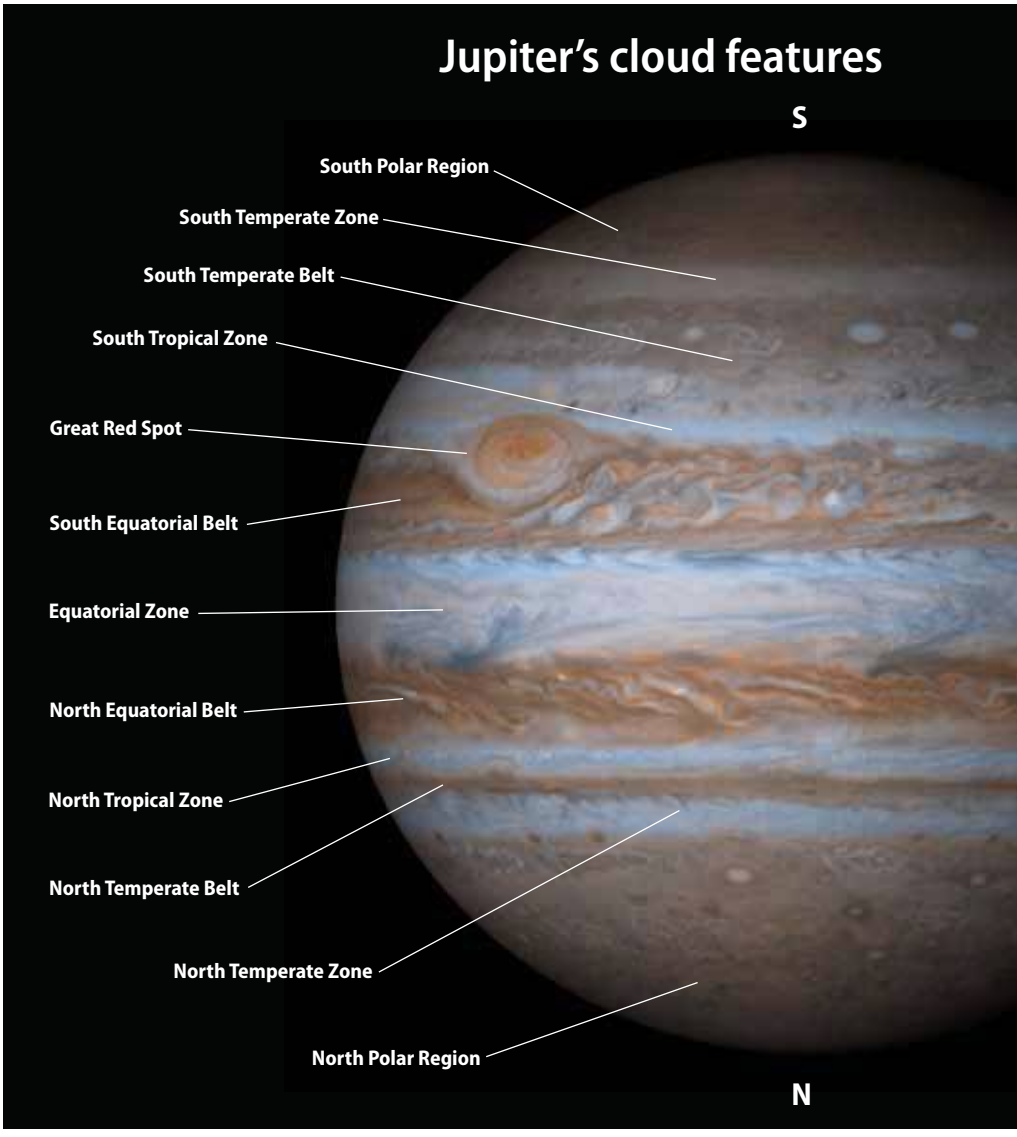
"The 2007 revival was perhaps not on as grand a scale as some in the past," Rogers notes, "but was still spectacular as it was covered in unprecedented detail thanks to modern amateur imaging. We can expect that the forthcoming revival will again occur in a spectacular outburst of storms and vortices. It could start at any time in 2010 or 2011."

Generally speaking, it takes a few months for the SEB's state of darkness to return fully back to "normal" once it starts. That leaves time for us to prepare and catch some of this violent activity.

Time to strip

The best way to keep track of temporal changes on Jupiter is to make strip sketches (detailed drawings of a specific area) of the activity. I recommend spending at least 10 minutes doing nothing but scanning the SEB and deciding what segment you want to draw. The longer you look, the greater your chances of catching rare moments of crisp seeing.

If you practice drawing segments of the SEB every clear night, you may surprise yourself by not only recording finer and finer details, but also capturing a moment of upheaval in Jupiter's history. Keeping track of changes can be a fun and unforgettable activity. As always, keep me posted on what you see (or don't see) by sending reports to someara@interpac.net.



Jupiter normally provides a varied and complex appearance for any interested observer. Simply because it's "lost" its South Equatorial Belt doesn't mean there's nothing to look at. NASA

Jupiter typically shines bright in our night sky, beckoning observers to study its mysterious appearance in ever-closer detail. Mike Salway

Put a ring on it A July 10 paper in *The Astrophysical Journal Letters* explains the giant gas ring in Leo as the result of a billion-year-old galactic collision.

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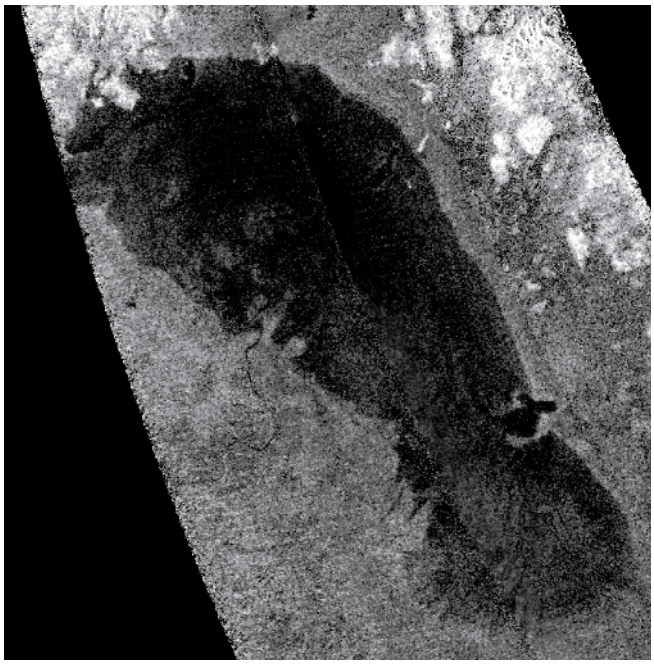


Bigfoot rules. Ontario Lacus, the largest lake in Titan's southern hemisphere, has shrunk noticeably as summer there has turned to fall. Radar observations show the depth of liquid methane in the lake has dropped about 3.3 feet (1 meter) during the past 4 years. NASA/JPL-Caltech

Lake levels recede on Titan

Scientists using data returned by the Cassini spacecraft's radar instrument found that the amount of liquid methane in lakes on Saturn's moon Titan has dropped during the past several years. The decline coincides with seasonal evaporation on the moon and mimics changes in water levels seen on Earth — the only other place in the solar system known to undergo a similar cycle.

Alexander Hayes and Oded Aharonson of Caltech led the team that measured the changes in lakes in Titan's southern hemisphere. The researchers found that in the largest lake, Ontario Lacus, the shoreline receded about 6 miles (10 kilometers) from June 2005 to July 2009 — from midsummer to early autumn on Titan. The lake's southern edge appears shallow and slopes gently while the northern edge butts up against a mountain range and has a steep slope.

"The extent to which the lake has receded is related to the slope — where the lake is shallow, the liquid has receded more," says Hayes. "This allows us to deduce the vertical height by which the lake depth has dropped, which is about 1 meter (3.3 feet) per year."

The scientists then compared this rate of methane evaporation to that seen in nearby lakes between December 2007 and May 2009. They got the same results. The team will report its findings in two upcoming papers, one in *Icarus* and the other in the *Journal of Geophysical Research*. — **RICHARD TALCOTT**

18 It's a comet! It's a planet! It's ... both?

18 Rosetta targets ancient Lutetia

19 Astronomers study massive star's disk

20 Prometheus starts giant snowball fight

21 Exoplanets discovered in unprecedented proximity

Champion star. The young star cluster R136a in the Large Magellanic Cloud hosts the largest star known. R136a1, which currently tips the scale at 265 times the Sun's mass but was born at more than 300 solar masses, lies at the center of this near-infrared image. ESO/P. Crowther/C. J. Evans

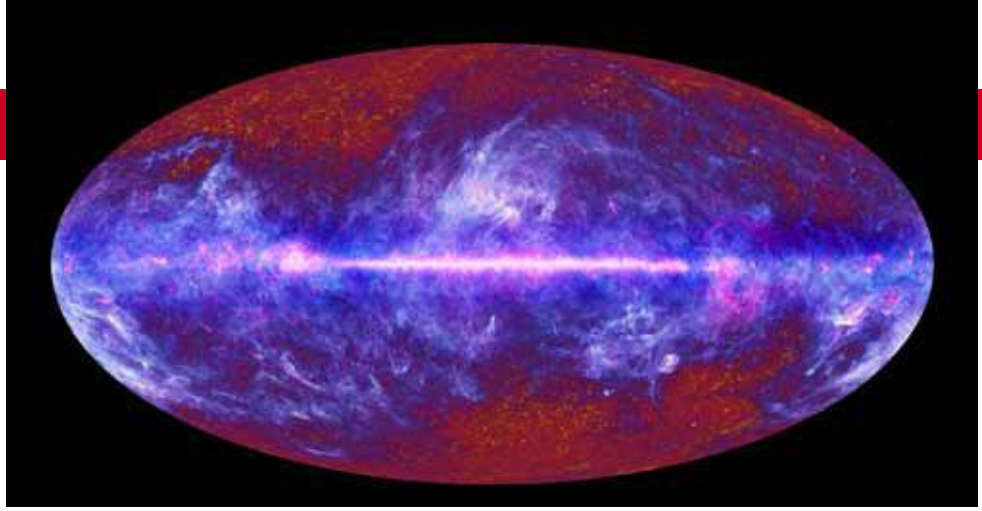
Found: the biggest star ever

Astronomers scouring the giant star cluster R136a in the Large Magellanic Cloud (LMC) have uncovered a star weighing some 265 times that of the Sun. Because such massive stars shed material rapidly as powerful stellar winds, researchers estimate it was born with up to 320 times the Sun's mass. That makes the star, cataloged as R136a1, the most massive and luminous known.

Astronomers have a hard time figuring out how such massive stars can exist. Most theories say stars heavier than about 150 solar masses should be unstable. But a team of researchers led by Paul Crowther of the University of Sheffield in England has found several stars that exceed this limit.

The team examined two young star clusters: R136a in the LMC and the Milky Way's NGC 3603. Using the European Southern Observatory's Very Large Telescope and data from Hubble, the team found four stars in R136a that began life with at least 165 solar masses, and three similar ones in NGC 3603.

How do such massive stars form? "Either they were born this big or smaller stars merged together to form them," Crowther says. The team reported its findings in the July 8 issue of the *Monthly Notices of the Royal Astronomical Society*. — **R. T.**



In the microwave. **This image combines 12 months of data from the Planck mission, which is mapping the universe's microwave emission.** ESA/HFI and LFI consortia

Planck sees 13 billion years of light

The NASA and European Space Agency's Planck satellite has steadily observed the entire sky for the past year. On July 6, scientists released the mission's first all-sky survey, which shows both our Milky Way Galaxy and the universe's light from 380,000 years after the Big Bang. Planck's purpose is to study this light, called the cosmic microwave background (CMB) radiation.

The satellite observes the microwave sky through nine filters. While gathering information about the CMB, it also captures microwave radiation from our galaxy and extragalactic sources. The Milky Way's disk is visible in this image as a horizontal plane in the center. The purple wisps are gas and dust in the galaxy; many of these regions house star formation.

The grainy structure toward the top and bottom of the image is the CMB. This radiation shows the seeds from which the universe's structure eventually grew. Over the next 2 years, scientists will identify and remove the emission from nearby sources (such as the Milky Way). The processed data — scheduled for release at the end of 2012 — will contain the best details yet of the CMB. Within the processed map, astronomers hope to find evidence of inflation, a period of hyperexpansion theorized to have occurred just moments after the universe's beginning. — **LIZ KRUESI**

NASA/ESA/Orsola De Marco (Macquarie University)

Peeking through the Stern's dust

Young pups. **Hubble strikes again, snapping this beautiful shot of NGC 2467, some 13,000 light-years away in Puppis the Stern. The unusually shaped dust clouds lie in front of a shimmering background of glowing gas, mostly hydrogen. Newly formed blue stars shine through some of the clouds, though many more remain hidden. NASA and the European Space Agency released the image July 13. — BILL ANDREWS**

QUICK TAKES

ARCHEO-GEO-BIOLOGY
An article in *Earth and Planetary Science Letters* available online July 17 describes clay-carbonate rocks on Mars similar to Earth rocks with evidence of early life.

BULLIED BLACK HOLE
A giant black hole's axis of rotation has moved, although the object itself hasn't; astronomers suspect an unknown force "jerked" it around. Details appeared in a July 1 *The Astrophysical Journal Letters* paper.

TINY MISTAKE
A study in the July 8 *Nature* shows that protons — one of the fundamental building blocks of matter — are 3 x 10^{-17} meters smaller than scientists thought.

SMALL ERROR
Neutrinos, one of the lightest and most elusive fundamental particles, are at most half as massive as researchers had estimated, according to work in the July 12 *Physical Review Letters*.

MASSIVE RESTRAINT
Fermilab announced July 26 it has ruled out about a quarter of the possible masses for Higgs bosons; the still-theoretical particle explains the nature of mass.

SUPERMASSIVE SLINGSHOT
Hypervelocity star HE 0437-5439 is likely the result of a triple system where the Milky Way's supermassive central black hole captured one star and the other two fused together, according to research in the August 10 issue of *The Astrophysical Journal Letters*.

UNDER PRESSURE
Plans for future experiments exposing water molecules to heavy ion beams in order to re-create the intense gravitational pressure Neptune imposes on its water appeared in the July 22 *New Journal of Physics*.

ICE JOB!
The IceCube Neutrino Observatory at the South Pole detected an unusual pattern in the relative intensity of cosmic rays — signals the telescope was not meant to study. The results appeared August 1 in *The Astrophysical Journal Letters*.

COMPLEX CARBON CATCH
The Spitzer Space Telescope detected the complex and large carbon molecules known as "buckyballs" in space for the first time in planetary nebula Tc 1, NASA announced July 22.

NASA/ESA/G. Bacon (STScI)

Cometary planet. **In this artist's conception, exoplanet HD 209458b orbits its sun as it trails atmospheric gases. This is the first such "cometary planet" ever discovered.**

It's a planet! It's a comet! It's ... both?

Exoplanet-junkies already may be familiar with gas giant HD 209458b, the first known extrasolar world with an atmosphere, the first to have its mass measured directly, and the first known to contain oxygen, carbon, and even potentially water vapor. Now it can add one more first to the list: the first known "cometary planet."

A July 10 study in *The Astrophysical Journal* suggests HD 209458b orbits so close to its star that the planet's atmosphere trails out behind it, giving the appearance of a comet's tail. "We have measured gas coming off the planet at specific speeds," says study leader Jeffrey Linsky of the University of Colorado in Boulder. "The most likely interpretation is that we have measured the velocity of material in a tail."

Lying 153 light-years from Earth, HD 209458b (unofficially called Osiris) is slightly less massive than Jupiter but orbits its star 100 times closer than Jupiter does the Sun. The exoplanet also travels significantly faster, completing an orbit in only 3.5 Earth days compared to Jupiter's 11.86 Earth years. Astronomers have long studied it because of its ideal orientation to Earth; it passes in front of, or transits, its star, giving observers several opportunities to study the light of both bodies.

Despite having its atmosphere continuously ripped away by the star's intense winds, HD 209458b will remain in scientists' sights for some time. "It will take about a trillion years for the planet to evaporate," Linsky says. — **B. A.**

Rosetta targets ancient Lutetia

On July 10, the European Space Agency's Rosetta spacecraft zipped past asteroid 21 Lutetia, giving eager planetary scientists their first close-up look at this survivor from the solar system's birth. Rosetta performed flawlessly during the encounter, swooping within 1,965 miles (3,162 kilometers) of the asteroid's battered surface.

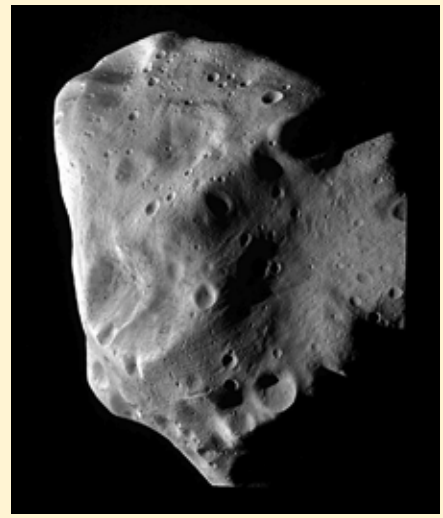
The images show a heavily cratered world, not unexpected for an object exposed to the crowded asteroid belt for 4.5 billion years. As Rosetta approached Lutetia, a giant bowl-shaped feature rotated into view. The depression stretched across much of the asteroid, whose longest side spans approximately 80 miles (130 km).

The stunning pictures came courtesy of Rosetta's OSIRIS instrument, which combines a wide-angle and narrow-angle camera. At the spacecraft's closest approach, the camera revealed details as small as 200 feet (60 meters) across.

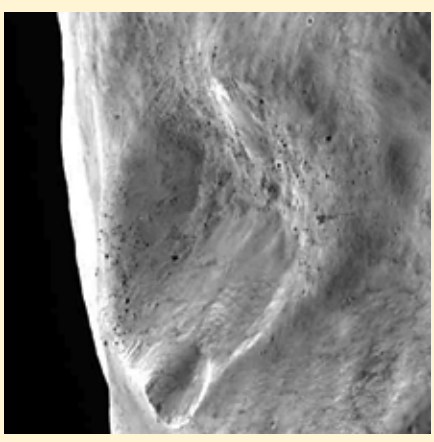
Although OSIRIS delivered almost immediate gratification to scientists on the ground, Rosetta had its entire suite of instruments turned on for the encounter. Together, they studied Lutetia's composition and density, searched for evidence of a tenuous atmosphere, and hunted for signs of a magnetic field. They even sought to catch any dust grains that might be floating near the asteroid. Analyzing these observations likely will take weeks or months.

Lutetia has intrigued planetary scientists for decades. Ground-based observations seem to show it has a split personality. In some respects, it resembles a C-type asteroid, primitive bodies that have remained largely unchanged except for impact cratering since the solar system's formation. But in other respects, Lutetia looks like an M-type asteroid, bodies scientists think are fragments created in collisions among much larger objects.

Following the Lutetia flyby, Rosetta is finally heading toward its ultimate target: Comet 67P/Churyumov-Gerasimenko. The spacecraft will rendezvous with the comet in 2014. It will then accompany the comet for several months as it makes its way from near Jupiter's orbit to its closest approach to the Sun. In November 2014, Rosetta will release the probe Philae, which will land on the comet's nucleus. — **R. T.**



Up close and personal. **Rosetta captured this full-disk view of asteroid 21 Lutetia at closest approach July 10.** ESA/MPS/OSIRIS Team

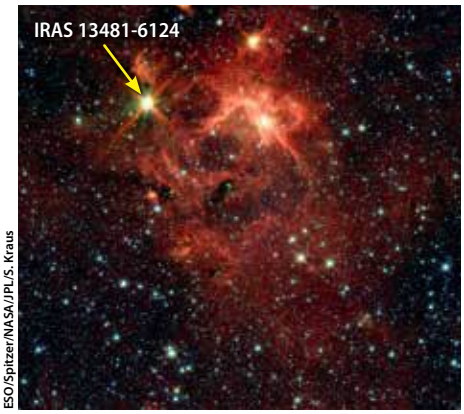


Bowled over. **This deep depression on Lutetia reveals large boulders and signs of a possible landslide.** ESA/MPS/OSIRIS Team

Groovy craters. **Deep shadows reveal plenty of craters and long fractures in this close-up view of the asteroid's surface.** ESA/MPS/OSIRIS Team

Earth(-sized) tones

An upcoming paper in the *Monthly Notices of the Royal Astronomical Society* describes a new method of detecting exoplanets sensitive enough to find Earth-sized objects, using minute gravitational deviations of stars' light.



ESO/Spitzer/NASA/JPL/S. Kraus

Dusty cradle. **In the upper left is a bright baby star still within its natal cocoon. Astronomers recently imaged a gas and dust disk surrounding this massive young sun, which is the first time a disk has been seen around a heavyweight.**

Astronomers study massive star's disk

An international team of astronomers has imaged a disk of gas and dust closely circling a massive young star. While scientists have seen such disks around stars similar in mass to the Sun, this is the first time one has been directly observed around a massive star. The team's finding appeared in the July 15 issue of *Nature*.

The team studied images of a star-forming region taken with the Spitzer Space Telescope and the Atacama Pathfinder Experiment (a 12-meter submillimeter telescope) and found a jet. It then used the Very Large Telescope Interferometer in Chile to analyze the area. "Such jets are commonly observed around young low-mass stars and generally indicate the presence of a disk," says lead author Stefan Kraus of the University of Michigan, Ann Arbor.

The resulting resolution of 2.4 milliarcseconds allowed the astronomers to detect the expected disk around IRAS 13481-6124. This star is about 10,000 light-years distant and holds some 20 times the mass of the Sun. They determined the star has reached its final mass, and the system is about 60,000 years old.

The intense radiation from this sun will soon begin to evaporate the disk. Scientists had long thought that massive stars' emission would blow away any surrounding gas and dust disks much earlier in the star-formation process. This finding provides evidence that heavy suns follow a formation path similar to that of less massive ones. — **L. K.**

NASA/ESA/R. O'Connell (University of Virginia)/F. Paresce (National Institute for Astrophysics Bologna, Italy)/E. Young (Universities Space Research Association/Ames Research Center)/the WFC3 Science Oversight Committee/Hubble Heritage Team (STScI/AURA)

Carving out a home for stars

Cavity search. **The southern constellation Carina contains some of the biggest star clusters in the Milky Way, but few compare with NGC 3603. The cluster lies some 20,000 light-years from Earth and holds some of the most massive stars in our galaxy. Violent stellar winds and ultraviolet radiation from the hottest stars have carved out an enormous cavity in the surrounding gas and dust, allowing us a clear view of the cluster. The Hubble Space Telescope took this image in visible and infrared light with its new Wide Field Camera 3. — R. T.**

Powerful jets spew from average black hole

A relatively small black hole 12 million light-years away has broken the record for the most powerful pair of emission jets astronomers have ever seen from an object of this size, according to a July 8 paper in *Nature*. The jets, a typical feature of stellar-mass black holes actively "eating" another object, also produce a huge bubble of hot gas as they push into the nearby interstellar gas. This bubble is some 1,000 light-years across, inflating at nearly 620,000 mph (1 million km/h).

"We have been astonished by how much energy is injected into the gas by the black hole," says lead author Manfred Pakull of the University of Strasbourg. "This black hole is just a few solar masses but is a real miniature version of the most powerful quasars and radio galaxies, which contain black holes with masses of a few million times that of the Sun."

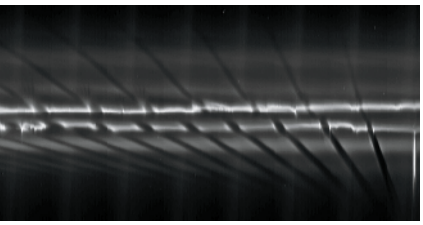
This particular black hole, also known as a microquasar because of its emissions, resides in the outer regions of spiral galaxy NGC 7793 in Sculptor. Its powerful jets are similar to those associated with supermassive black holes, suggesting a link between such frequently observed phenomena and the relatively scarce microquasar jets.

ESO/L. Calçada/M. Kornmesser

Cool your jets. **As a black hole devours another object, it sends jets of particles flying at incredible speeds, as this illustration depicts. Astronomers have discovered the most powerful emission jets ever seen from a stellar-mass black hole in spiral galaxy NGC 7793.**

"The length of the jets in NGC 7793 is amazing compared to the size of the black hole from which they are launched," says co-author Robert Soria of University College London. "If the black hole were shrunk to the size of a soccer ball, each jet would extend from Earth to beyond the orbit of Pluto." — **B. A.**

Lupe-y quasar A study in the July 16 *Astronomy & Astrophysics* describes the first known case of a quasar acting as a gravitational lens, magnifying a far-off galaxy.



F ring shenanigans. Saturn's moon Prometheus interacts with the tenuous F ring (the horizontal strip across this image's center), creating bright fan-shaped regions where particles bunch up and stick together. Eventually, they can form icy objects up to 12 miles (20 km) across. NASA/JPL/SSI

Prometheus starts giant snowball fight

Saturn's potato-shaped moon Prometheus may be small, measuring just 92 miles (148 kilometers) through its longest axis, but it has a big impact on Saturn's thin, kinky F ring. New images from the Cassini spacecraft show the moon's gravitational pull stirring up icy particles in the F ring and triggering the formation of giant "snowballs" up to 12 miles (20 km) in diameter.

"Scientists have never seen objects actually form before," says Cassini imaging team member Carl Murray of Queen Mary, University of London. "We now have direct evidence of that process and the rowdy dance between the moons and bits of space debris." Murray discussed the findings July 20 at the Committee on Space Research meeting in Bremen, Germany.

Prometheus cruises around Saturn at a slightly greater speed than the F ring particles. As a result, the moon laps the particles and stirs up the same region once every 68 days. "Some of these objects will get ripped apart the next time Prometheus whips around, but some escape," adds Murray. "Every time they survive an encounter, they can grow and become more stable." — **R. T.**

Life precursors in Titan's atmosphere

Researchers at the University of Arizona in Tucson have discovered what type of organic substances scientists might find on the saturnian moon Titan's surface, and how those compounds might form. Their findings appeared in the July 13 issue of the *Proceedings of the National Academy of Sciences*.

The scientists zapped a nitrogen and methane gas blend with ultraviolet radiation to mimic how solar radiation affects Titan's atmosphere. They found most of the nitrogen changed directly into solid compounds, which could eventually lead to life. Previous models stated the nitrogen would take a lengthier process to convert from gas to solid form.

A smog of organic molecules envelops the saturnian satellite. NASA's Cassini mission has found evidence that ultraviolet radiation hitting Titan's atmosphere is creating complex organic molecules. The researchers believe that the particles form in the atmosphere and eventually settle onto the surface. — **L. K.**

BRIEFCASE

X-Rays blind Swift

On July 14, astronomers reported that a June 21 gamma-ray burst emitted so many X-rays that it overwhelmed the detectors on NASA's Swift observatory, temporarily "blinding" it. Although the blast took place 5 billion light-years away, it ranks as the brightest X-ray source ever seen beyond the local universe. — R. T.

The best Mars map ever

Using nearly 21,000 images from the Thermal Emission Imaging System on NASA's Mars Odyssey spacecraft, researchers at Arizona State University and NASA's Jet Propulsion Laboratory have compiled an exquisite global map of the martian surface. People can view the zoomable map at www.mars.asu.edu/maps. At full zoom, the smallest details visible are 330 feet (100 meters) across. — R. T.

Strengthening the dark energy case

Astronomers use type Ia supernovae to measure the acceleration of cosmic expansion caused by dark energy. Such supernovae make excellent "standard candles" because they all form the same way (when a white dwarf explodes) and thus should have similar luminosities. Yet some blasts that otherwise look like twins show diverse spectral features. Now, a group led by Keiichi Maeda of the University of Tokyo argues that type Ia supernovae can explode asymmetrically. This would explain the different spectral appearances and confirm type Ia blasts as good standard candles. — R. T.

25 years ago in *Astronomy*

November 1985

In the November 1985 issue, Stephanie and John Mood wrote about "Palomar and the Politics of Light Pollution." Interspersed with telling pictures and graphs, the Moods described the arduous process of keeping the sky dark over the San Diego area. "Astronomers are going to have to become what they never wanted to be: politically astute and active."

A quarter-century later, though, John Mood says their success was only fleeting: "We had simply won a battle. The war was later lost." Despite the good work that resulted, he says the sleaze of city councils and county boards was exhausting. "We were too tired to take the next step of legal haggling, and those new to the fight rejected that approach. In the interim, sky glow has increased dramatically over every city in the world."

November 2000

10 years ago in *Astronomy*

The November 2000 issue featured a behind-the-scenes story on the profession of astronomy with "Good Morning, Gentlemen and Meg." Ann Finkbeiner wrote about the relatively low number of women in astronomy and the hurdles they face. "Women are half of the labor force and a fifth of all scientists and engineers but still under a tenth of all astronomers," she wrote. Whether it's a lack of role models, unfair treatment, or even outright discrimination, women face a number of obstacles that men simply didn't throughout their careers.

The title actually comes from an example of the inadvertent isolation such women faced. Meg Urry, then of the Space Telescope Science Institute, often attended graduate lectures that began, "Good morning, gentlemen and Meg." "Such incidents," Finkbeiner wrote, "are evidence to women that they're outsiders." — **B. A.**

Exoplanets discovered in unprecedented proximity

For the first time, astronomers have found pairs of exoplanets so close together, they've influenced one another's orbits.

In an upcoming paper in *The Astronomical Journal*, California Institute of Technology professor John Johnson and his colleagues discovered two systems with extremely close planets, one around star HD 200964 and the other around star 24 Sextanis.

"There are many locations in a protoplanetary disk where planets can form," says Johnson. "It's very unlikely, however, that two planets would just happen to form at locations where they have [stable, interacting] periods." This has led astronomers to suspect the planets of migrating from their original positions so they'd "cross paths and jostle each other around" until settling into their current orbits.

All four planets are gas giants more massive than Jupiter that orbit their stars much closer and faster than our jovian giant. Scientists discovered them by measuring the slight wobble of their parent stars, currently the leading method of finding exoplanets.

"This is the latest in a long line of strange discoveries about extrasolar planets," says Johnson, echoing many of his colleagues' sentiments. "It shows that exoplanets continuously have this ability to surprise us. Each time we think we can explain them, something else comes along." — **B. A.**

Orbital embrace. **Multiple exoplanets have been found orbiting the same star, as in this artist's rendering, but a recent discovery has uncovered two pairs of exoplanets orbiting so close to one another that they interact gravitationally.** NASA/JPL

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The Kepler space oth

Johannes Kepler decoded how the Sun's planets move. Now the spacecraft named after him hunts for other planetary systems. **by C. Renée James**

On March 6, 2009,

a United Launch Delta II rocket shot into the night sky over Cape Canaveral, Florida. It carried a fairly modest package, technologically speaking: 42 CCD detector arrays and a 1-meter Schmidt telescope. It also had the simplest of directives: to spot variations in the intensity of starlight.

Why make a spacecraft just for this purpose? Because maybe, just maybe, those variations would help us find worlds like our own.

By mid-summer 2009, almost exactly 4 centuries after its namesake had solved the riddle of planetary motion, the Kepler mission had five newly discovered planets under its belt. Although these were "hot Jupiters" — gas giant planets close to their suns — the craft was well on its way to helping us figure out the nature of solar systems.

"If the mind had never shared an eye, then it would … demand the eye and prescribe its own laws for forming it." — *Johannes Kepler, 1619,* Harmonice Mundi ("*Harmony of the World*")

In 1984, when the idea for a photometric method to detect Earth-sized planets hatched in Principal Investigator Bill Borucki's mind, the first definitive extrasolar planet discovery was still 8 years away. Unlike the case for the spectroscopic approach to planet detection, which looks for

craft's search for

er worlds

The Kepler spacecraft is on the hunt for extrasolar planets. While it will detect gas giants close to their suns, its main goal is to find Earth-sized planets. To help verify Kepler's discoveries, astronomers will utilize historic astronomer Johannes Kepler's three laws of planetary motion. Lynette Cook for *Astronomy*

Johannes Kepler was a prominent astronomer and mathematician in the late 1500s and early 1600s. His laws of planetary motion — the culmination of his work — are a staple in introductory astronomy courses and textbooks. Copy of anonymous 1610 portrait

Follow-ups and false positives

You've just spotted a dip in the light curve in Kepler's data. Now what? As Nick Gautier of NASA's Jet Propulsion Laboratory points out, there are a half dozen common scenarios that it could be that aren't what scientists are looking for. In the first step, astronomers scrutinize the individual pixels around the star's image. If the culprit is a background eclipsing binary star, for example, the center of the image itself will have a noticeable shift. Planets also tug their stars around, but to a lesser degree, so Kepler astronomers scour the pixels for clues about the properties of the objects involved.

If the dimming event survives this first round of elimination, astronomers then designate it a Kepler Object of Interest, or KOI. In the first quarter of operations in 2009, Kepler scientists culled out 177 KOIs and directed ground-based astronomers at one of the many Kepler partner institutions to take the characteristic light spectrum of each target. William Cochran of the University of Texas at Austin is one such follow-up observer. "We try to see first of all if it is a composite spectrum," Cochran says. "Are we seeing more than one star there? And then we decide if we get rough agreement with the stellar parameters derived from photometry."

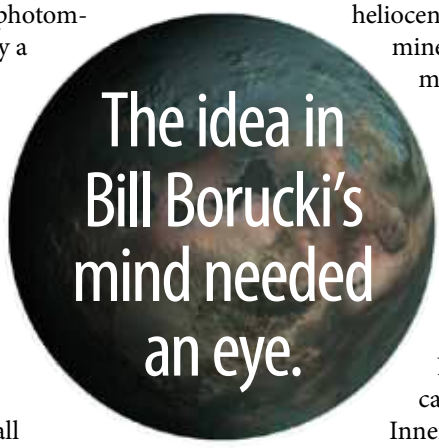
Astronomers can spot binary stars that sneak through the first phase of elimination thanks to their predictable, large, periodic effect on the spectrum. At this level, spectra will also reveal hot Jupiters, like Kepler's first five verified planet-finds.

After the targets pass the spectrum phase, astronomers use either the Keck or the Hobby-Eberly Telescope for high-precision radial velocity work. Of the 177 original KOIs, 52 possible planets had advanced to this phase, and dozens more are still having their spectra analyzed. It is during this high-precision phase that astronomers try to determine an orbit for the object to find out whether it is a habitable, earthlike planet. How? By applying Kepler's laws, of course. — *C. R. J.*

minute shifts in spectral lines as an orbiting planet tugs its star to and fro, the concept behind photometric planet detection is more basic. Quite simply, when a planet passes in front of a star, the light intensity diminishes. Bigger planets mean bigger dips in the light curve.

But the idea in Borucki's mind needed an eye — a really sensitive one. "I told him he was completely nuts," laughs McDonald Observatory's William Cochran, who first discussed the project with Borucki in 1984. In those days, photometry wasn't up to the task of detecting roughly a 1-in-10,000 percent drop in light intensity, which is the sensitivity required to detect an Earth-sized planet around a Sun-like star. Technology would have to, as Kepler wrote, "prescribe its own laws for forming" the appropriate eye, a task Cochran and others seriously doubted was in the cards. But Borucki would not be discouraged, and even Cochran says he was "converted from a skeptic to a true believer."

"Because [Borucki] is such a determined bulldog, he just went and one by one solved all the problems that people said would prevent it from ever working," Cochran explains. But it wasn't easy or fast. Solving these problems ultimately required the aid of eight institutional partners, more than 30 scientists, and scores of software designers and instrumentation engineers, collectively contributing more than a million man-hours of labor.



By 1992, long before it required a concert hall to house everyone who had ever worked on the project, the basic framework of the Kepler mission was coming together. Instrument scientist Ted Dunham of Lowell Observatory was one of a handful of astronomers involved in the planning. "This was the period when we decided to try CCDs as the detectors, chose the heliocentric orbit, picked the Delta II launcher, determined the size of the optics, decided not to have a mechanical shutter, chose the approximate location of our field of view, and began working with Ball Aerospace," Dunham explains.

Even so, it would be nearly another decade before NASA selected the idea as a Discovery Program mission, thereby adding it to now-familiar projects like Stardust, MESSENGER, NEAR, Deep Impact, and the Mars Pathfinder. In 1996 and 1998, NASA turned down Kepler — originally called FRESIP, for Frequency of Earth-Sized Inner Planets — for funding. At the same time, many members of the astronomical community blasted the project for its ambitious goal of detecting puny terrestrial planet transits in a universe of potential false positives: eclipsing binaries, starspots, and even instrumentation and data analysis flaws.

Jokes Jon Jenkins of the Search for Extraterrestrial Intelligence (SETI) Institute, who has been involved with Kepler since 1995, "It felt a lot like Charlie Brown and Lucy with all

C. Renée James *is an associate professor of physics at Sam Houston State University. In December 2010, Johns Hopkins University Press will publish her book,* Seven Wonders of the Universe That You Probably Took for Granted.

the proposal cycles." Even when NASA announced December 21, 2001, that it had selected Kepler, there was a lingering feeling that the football could still be pulled out from under them. "The truth set in sometime around 2003," Jenkins says, "once we started acquiring flight hardware."

None of it would have been a reality, however, were it not for its namesake who began pondering the rules of planetary motion 4 centuries earlier.

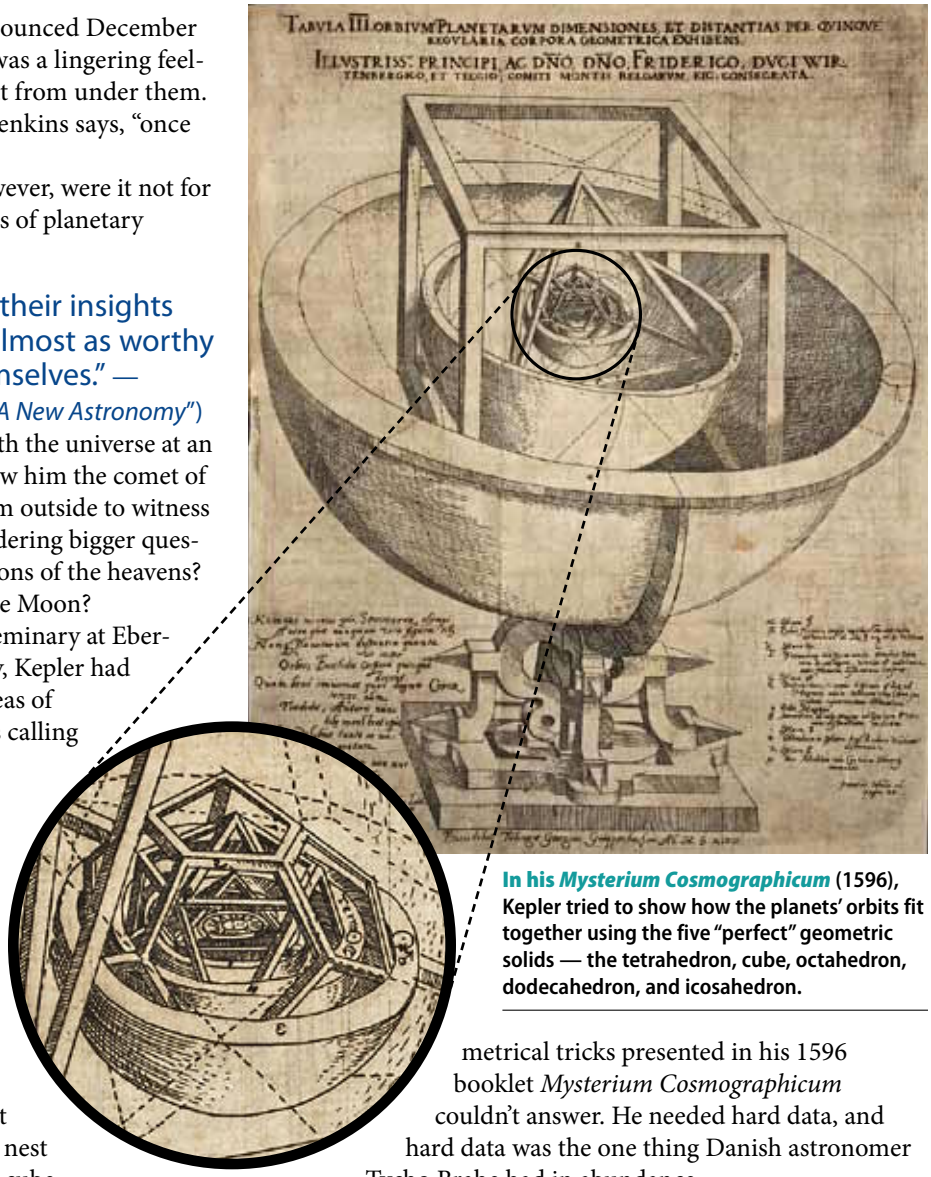
"The roads by which men arrive at their insights into celestial matters seem to me almost as worthy of wonder as those matters in themselves." — *Johannes Kepler, 1609,* Astronomia Nova ("*A New Astronomy*")

Johannes Kepler developed a fascination with the universe at an early age. His mother made it a point to show him the comet of 1577 when he was 5; at 8, his father took him outside to witness a lunar eclipse. Later, he found himself pondering bigger questions: Was Copernicus right about the motions of the heavens? How would things appear if viewed from the Moon?

Even before being accepted to the Stift seminary at Eberhard Karls Tübingen University in Germany, Kepler had demonstrated remarkable abilities in the areas of astronomy and geometry, but he still felt his calling lay in the ministry. And, were it not for his youthful appearance, he might have gone immediately from the seminary to the pulpit. Instead, he was deferred, and in 1594 went to Graz, Austria, to become a math teacher and district mathematician.

By all accounts, Kepler was an abysmal teacher, facing a completely empty classroom in just his second term. In the time he might have spent grading papers, Kepler instead busied himself with exploring the mysteries of the heavens. An attempt to inscribe the orbits of the planets within a nest of the five perfect solids — the tetrahedron, cube, octahedron, dodecahedron, and icosahedron (shapes familiar to anyone who has ever played *Dungeons & Dragons*) — was ultimately a frustration and a failure.

But the questions about planetary orbits haunted him. There was something significant about their spacing and motions — but what? Kepler had questions that the mysticism and geometrical tricks presented in his 1596 booklet *Mysterium Cosmographicum* couldn't answer. He needed hard data, and hard data was the one thing Danish astronomer Tycho Brahe had in abundance.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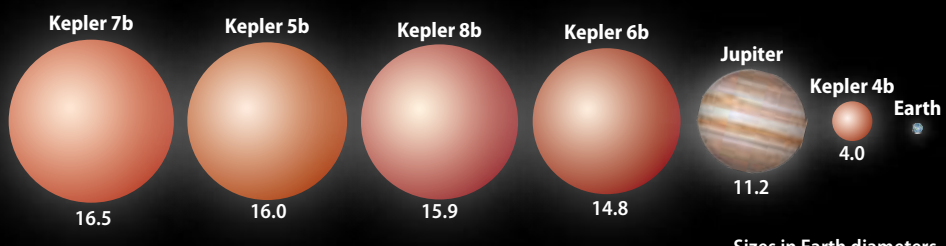
Linda Hall Library of Science, Engineering, and Technology

In his *Mysterium Cosmographicum* (1596), Kepler tried to show how the planets' orbits fit together using the five "perfect" geometric solids — the tetrahedron, cube, octahedron, dodecahedron, and icosahedron.

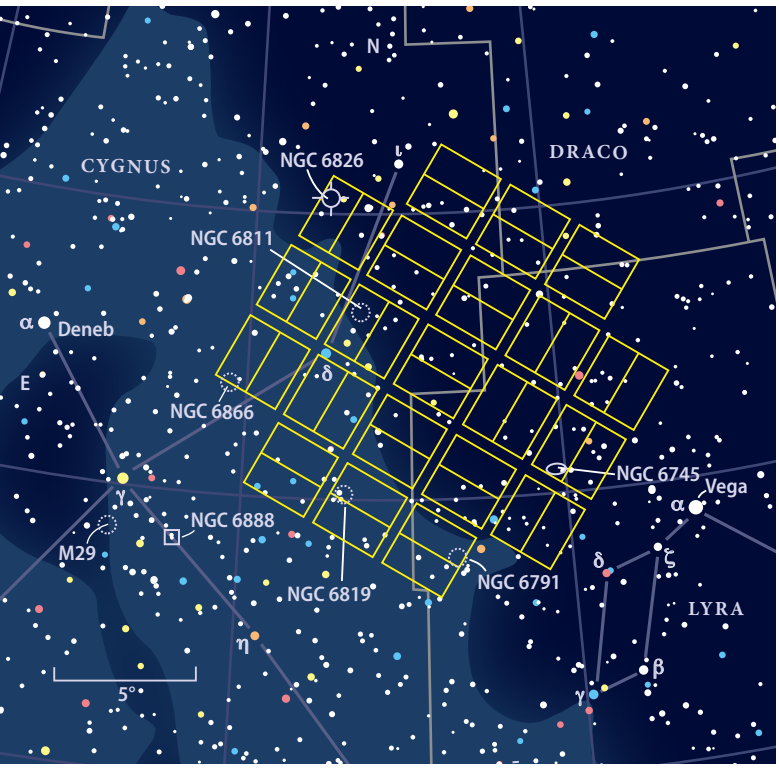
Fortunately for Kepler, Brahe was one of the few who had read his booklet, and he immediately realized that Kepler's mathematical talents could be useful. Thus, one of the most important and turbulent scientific collaborations in history was forged.

In 1600, Brahe's naked-eye data were state of the art — the Renaissance equivalent to measuring a 1-part-in-10,000 change in light intensity. He had amassed years of precise measurements of the locations of the Moon, planets, and stars in an attempt to prove his own hybrid version of the universe: The planets Mercury, Venus, Mars, Jupiter, and Saturn moved around the Sun, but the Sun dragged the whole entourage around a fixed Earth. His only problem was that he lacked the skills to fit the observations to a mathematical model. So in 1600 he called on the mathematical genius of Kepler, who jumped at the chance to access Brahe's observations, all the while despising Brahe's "patchwork" universe.

Kepler's first five



The Kepler spacecraft discovered five planets in data from its 10-day trial run. All are close to their suns and large — four are bigger than Jupiter and one is about Neptune's size. Astronomers do expect the mission will detect Earth-sized planets over the next few years. *Astronomy:* Roen Kelly, after NASA



Astronomy: Roen Kelly, after NASA/Software Bisque

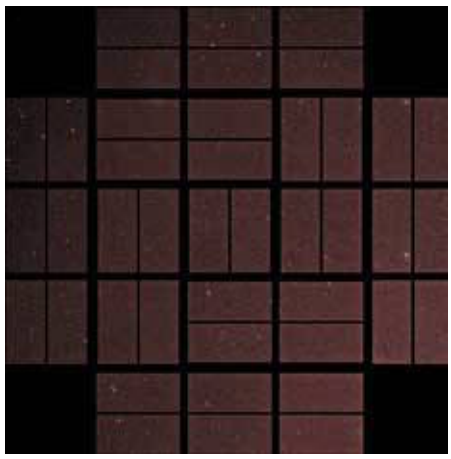
Kepler's field of view covers 100 square degrees, allowing the spacecraft to stare at nearly 170,000 stars over its 3.5-year lifetime.

Brahe decided that Kepler would start with the most troublesome planet: Mars. An overconfident Kepler claimed that he would be able to solve that problem in 8 days. Instead, the problem outlived Brahe, who died in 1601. Only after 5 years of agonizing calculations did Kepler hit upon two of his three "laws" of planetary motion: Orbits are ellipses with the Sun at one focus, and a planet's orbital speed varies depending on its distance from the Sun. Then in 1618, he determined that the orbital periods of the planets were related to their average distance from the Sun — his third law.

All in all, Kepler endured nearly 17 years of computational stops and starts, political turmoil, devastating personal tragedies (including the 1611 loss of his 6-year-old son to smallpox), legal fights over the late Brahe's data, and funding struggles to arrive at three simple statements that every introductory astronomy student now dutifully memorizes.

"… if you want the exact moment in time, it was conceived mentally on 8th March in this year one thousand six hundred an[d] eighteen, but submitted to calculation in an unlucky way, and therefore rejected as false, and finally returning on the 15th of May." — *Johannes Kepler, on the creation of his third law of planetary motion, 1619*, Harmonice Mundi ("*Harmony of the World*")

The Kepler mission has seen its own share of ups and downs, even after getting the green light. The biggest persistent issue has been funding woes. According to Ron Gilliland of the Space Telescope Science Institute, who has been with the project for the past 15 years, cost overruns required a redesign of the antenna and abbreviated certain tests of the detector electronics.



One month and 2 days after launch, the Kepler spacecraft took its first images of the area in which it would search for planets. Each rectangle represents one of the mission's 42 CCDs. Its entire field of view holds about 4.5 million stars, almost 170,000 of which Kepler monitors for minor brightness changes.
NASA/Ames/JPL-Caltech

Furthermore, Gilliland explains that the area of asteroseismology (the study of the internal structures of stars via observing pulsations) was removed from the funded project years ago, forcing those Kepler scientists to look beyond NASA for financial support. Gilliland concedes, "There were many challenges faced by the mission between the December 2001 award and the March 2009 launch. Fortunately, none reached levels that could be viewed as catastrophic."

Still, as the spacecraft sat on the launch pad nearly 391 years after Kepler first hit upon his third law of planetary motion, the scientists had concerns. Jenkins, who had seen his share of both successful and disastrous space launches, had no illusions: "That's when something can go wrong, and it can go wrong very quickly. All your hopes and dreams are relying on this rocket."

Dunham sums it up: "Launch is a pretty brutal affair."

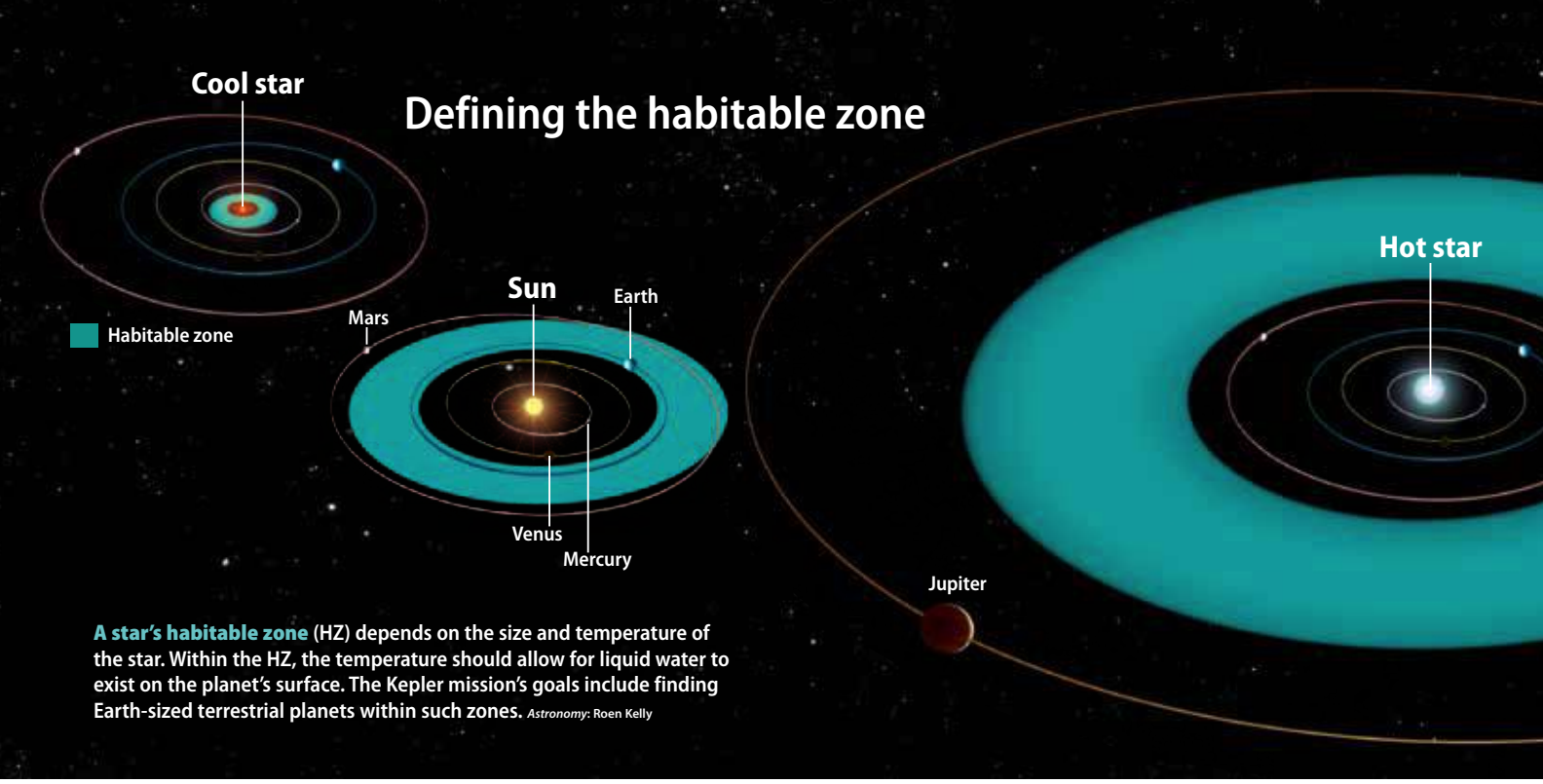
Fortunately, Kepler's launch was picture perfect. But the craft wasn't out of the woods yet. For a month, the intrepid spacecraft

Not just a one-trick pony

Neither Johannes Kepler nor the Kepler mission is single-minded. Although Johannes Kepler is generally regarded as the formulator of Kepler's laws of planetary motion, he also did groundbreaking work in the field of optics. His 1611 work, *Dioptrice*, is basically a textbook for a modern-day optics course.

Also along the way, he created a mathematical method that many consider a precursor to calculus, demonstrated how logarithms work, was the first to predict planetary transits in our solar system, and spent years compiling the *Rudolphine Tables* that contain stunningly precise astronomical data and predictions based on Tycho Brahe's observations.

Not to be outdone by its namesake, the Kepler mission is concerned with more than just planetary transits. False positives might be a frustration for planet hunters, but those can help astronomers better understand stellar sizes and masses, starspots, accreting stars, flare stars, stellar rotations, stellar pulsations (more than 250 astronomers are part of the asteroseismology team interested in this aspect of the mission, although their funding comes from sources outside NASA), and more. To see what sort of additional science is being done, check out the Kepler Guest Observer Program at http://keplergo.arc.nasa.gov. — *C. R. J.*



A star's habitable zone (HZ) depends on the size and temperature of the star. Within the HZ, the temperature should allow for liquid water to exist on the planet's surface. The Kepler mission's goals include finding Earth-sized terrestrial planets within such zones. *Astronomy*: Roen Kelly

slid farther and farther behind Earth, the only data being "dark frames" to determine noise issues with the instrument itself.

Finally, on April 7, 2009, Dunham allowed himself to exhale. By that time, Kepler trailed more than 1.8 million miles (3 million kilometers) behind Earth and successfully released its dust cover to take its first image, indicating that everything was working well. Less than a month later, Kepler began a 10-day gaze at 53,000 stars. This period was intended as a sort of practice run for the real science program, which currently involves monitoring approximately 170,000 stars. But using data from those 10 days — just a bit longer than Johannes Kepler's original estimate for figuring out the orbit of Mars — astronomers discovered five new planets.

And in June of this year, the Kepler team released data from the mission's first 43 days of observing. This information contains 306 exoplanet candidates, and the team is investigating 400 more. It expects to release these results in early 2011.

"I used to measure the heavens, now I shall measure the shadows of the Earth." — *Johannes Kepler*, self-authored epitaph

"It was just breathtaking to see the first data come off," recalls Jenkins. "You didn't even need to actually process the data to see the planetary signatures."

Finding giant planets close to their suns isn't in Kepler's job description, though. After all, ground-based technology has been doing that for more than a decade. What the Kepler team needed was verification that it could detect the 1-part-in-10,000 dip in light intensity caused by a terrestrial planet. Interestingly, Kepler's hot Jupiters discovery could help with that as well.

By analyzing the light curve from HAT-P-7b, a known close-in giant planet, the Kepler team found what they were looking for. As HAT-P-7b orbited its star, the transit of the planet in front of the star yielded the predicted large decrease in light. Exactly half an orbit later, the star eclipsed the planet, creating another, but much shallower, dip in the light curve.

The reason behind this so-called secondary occultation is simple. The sunny sides of these hot Jupiters can reach nearly 4500° Fahrenheit (2500° Celsius), glowing visibly. Just before slipping behind its star, a planet is showing us its hottest, brightest side. As the planet disappears from view, the star blocks this light. Although the contribution to the overall light in the system is minimal — about 1 part in 10,000 — the signature of this secondary occultation is unmistakable, and the Kepler satellite found it.

As Jenkins states, "That was the eureka moment. We really had something that would give us the precision to find Earth-sized planets," whose transit across the face of a Sun-like star would also yield a comparable dip.

So now the hunt is on. Hot Jupiters are fine, but the mission's main goal is to find Earth-sized planets orbiting in their stars' habitable zones — in a sense doing what Johannes Kepler prophesied for himself on his epitaph. This means finding planets with orbital periods far longer than the scant 3- to 4-Earth-day years of Kepler's first five planets, and this means patience and perseverance on the part of the vast Kepler team.

But that would have suited Johannes Kepler just fine. "His life is a study in perseverance," says Jenkins. "He managed to find beauty in the work that he did, and that's what many of us in this field do."

For more information about Johannes Kepler's life and his other discoveries, visit www.Astronomy.com/toc.

The biggest eyes on the sky

Nearly 50 giant telescopes probe the cosmos from Earth's surface.

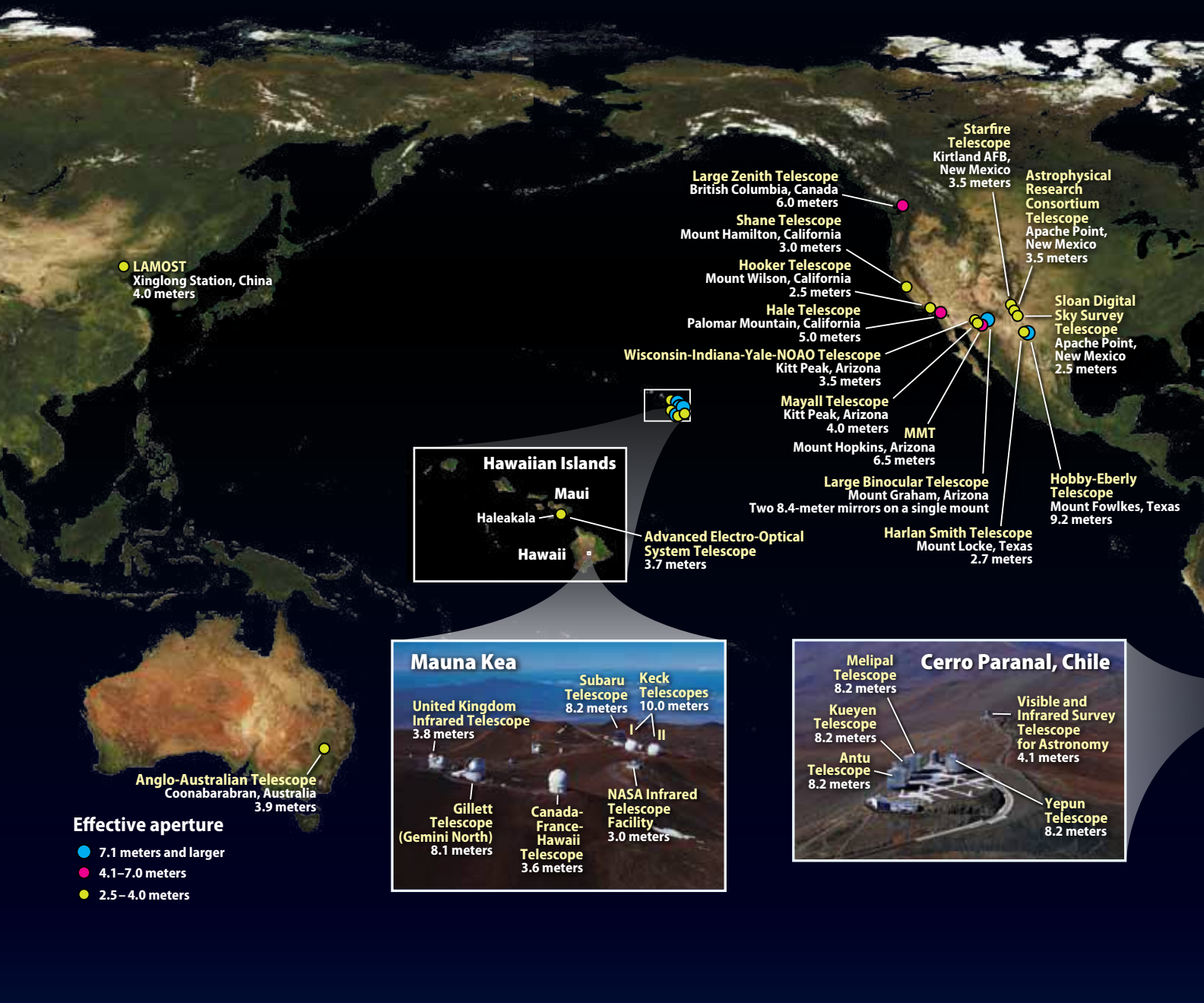
by Richard Talcott; graphics by Roen Kelly

Four hundred years ago, Galileo transformed our view of the universe when he first turned his telescope toward the sky. He saw the Moon as imperfect, four moons circling Jupiter, and Venus going through phases. The great scientist's observations helped overthrow the prevailing scientific beliefs of his time and helped place the Sun in its proper position at the center of the solar system.

And he did it all with a telescope just 1 inch in diameter. Galileo fashioned his telescope from glass lenses, which refracted the light passing through them to form images. Such refracting telescopes were all the rage among observers until 1668, when Isaac Newton built the first reflecting telescope (like Galileo's, 1 inch in aperture) that used a mirror to gather and focus light.

But small telescopes can do only so much. Bigger scopes collect more light

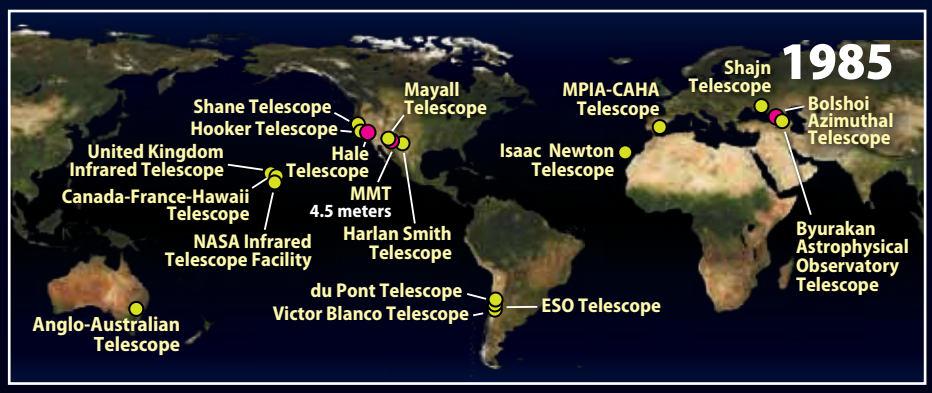
Richard Talcott *is a senior editor of* Astronomy *and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*



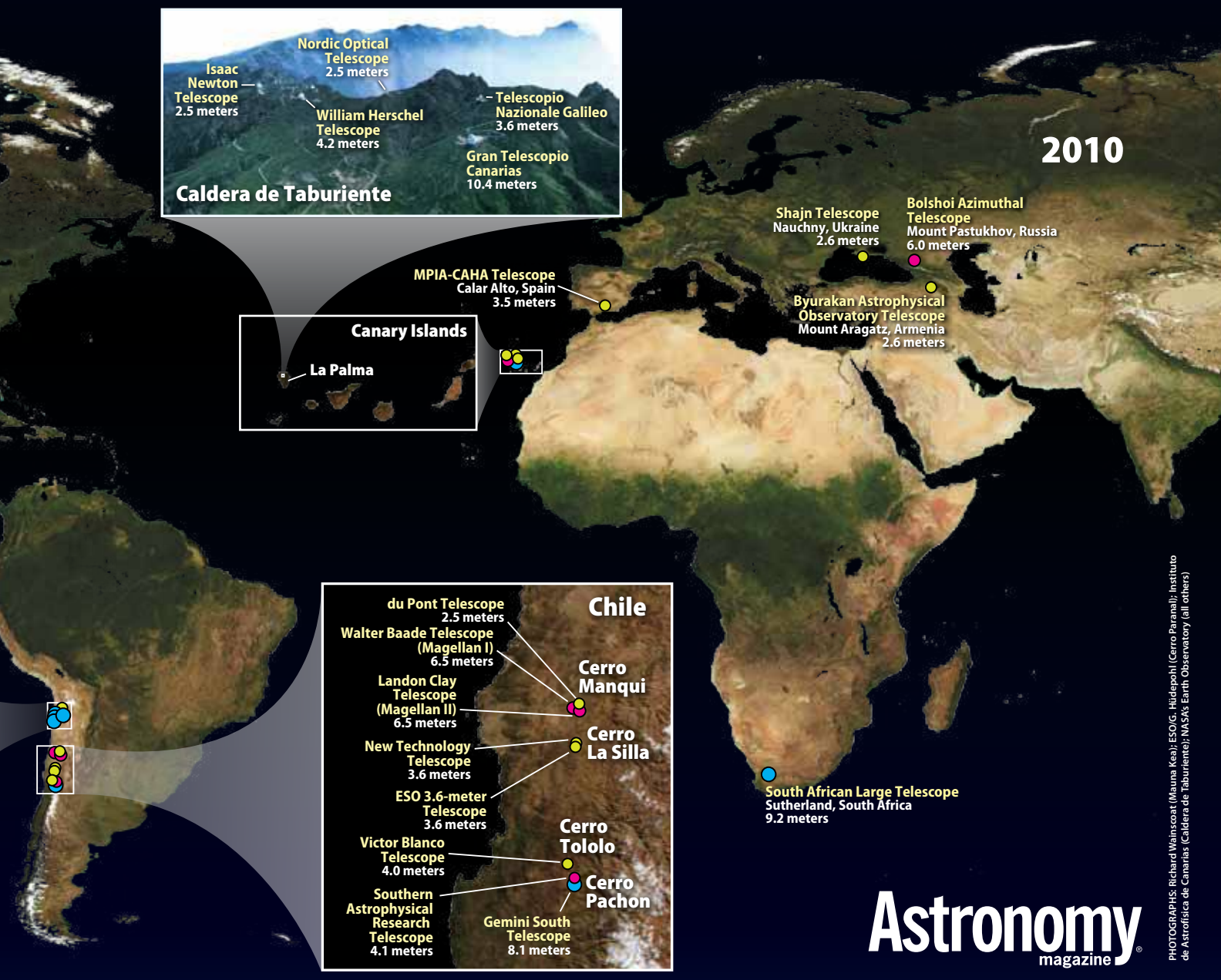
and reveal finer detail. The technology needed to build larger scopes advanced slowly, however. American astronomer George Ellery Hale oversaw construction of the first 2.5-meter (100 inches) telescope in 1917. The Hooker Telescope still stands on Mount Wilson in California, overlooking Los Angeles.

The next record came in 1948 with another Hale project, the 5-meter (200 inches) Hale Telescope on California's Palomar Mountain. By the late 20th and early 21st centuries, big scopes were popping up around the world, mostly on isolated mountaintops where the skies are clear and steady.

The map below shows the locations of all operating optical and infrared telescopes on Earth at least 2.5 meters in diameter. Note the large concentrations in Hawaii, Chile, and the Canary Islands. The map above shows big scopes just 25 years ago, a good reminder that we live in a golden age of astronomy.



The big eyes a quarter-century ago didn't measure up to today's giant telescopes. In 1985, only two scopes — the Hale and Bolshoi Azimuthal — were 5 meters across. Today, 19 reach that threshold.


Caldera de Taburiente
Isaac Newton Telescope 2.5 meters
Nordic Optical Telescope 2.5 meters
William Herschel Telescope 4.2 meters
Telescopio Nazionale Galileo 3.6 meters
Gran Telescopio Canarias 10.4 meters
2010
Shajn Telescope Nauchny, Ukraine 2.6 meters
Bolshoi Azimuthal Telescope Mount Pastukhov, Russia 6.0 meters
Byurakan Astrophysical Observatory Telescope Mount Aragatz, Armenia 2.6 meters
MPIA-CAHA Telescope Calar Alto, Spain 3.5 meters
Canary Islands
La Palma
South African Large Telescope Sutherland, South Africa 9.2 meters
Chile
du Pont Telescope 2.5 meters
Walter Baade Telescope (Magellan I) 6.5 meters
Landon Clay Telescope (Magellan II) 6.5 meters
Cerro Manqui
New Technology Telescope 3.6 meters
Cerro La Silla
ESO 3.6-meter Telescope 3.6 meters
Victor Blanco Telescope 4.0 meters
Cerro Tololo
Southern Astrophysical Research Telescope 4.1 meters
Cerro Pachon
Gemini South Telescope 8.1 meters

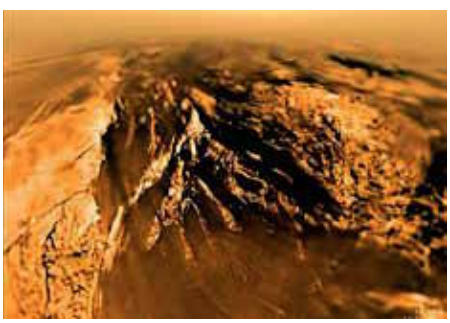
PHOTOGRAPHS: Richard Wainscoat (Mauna Kea); ESO/G. Hüdepohl (Cerro Paranal); Instituto de Astrofísica de Canarias (Caldera de Taburiente); NASA's Earth Observatory (all others)

Astronomy magazine

Cassini's top 10 SATURN system discoveries

Earthlike landscapes, one-of-a-kind storms, and painted faces are just a few of the surprises the Cassini mission found in the Ringed Planet's neighborhood. **by Rosaly Lopes**

The Cassini mission will enter the history books as a landmark in planetary exploration. The mission's prolific discoveries of Saturn and its system are hard to enumerate, let alone narrow down for a top 10 list. After 6 successful years, though, it is useful to look back and see how far we have come in our knowledge of the saturnian system. Cassini is now embarking on a second extended phase (the Cassini Solstice Mission) that will last through 2017. Then the spacecraft will enter Saturn's atmosphere, vaporize, and become part of the ringed planet forever.

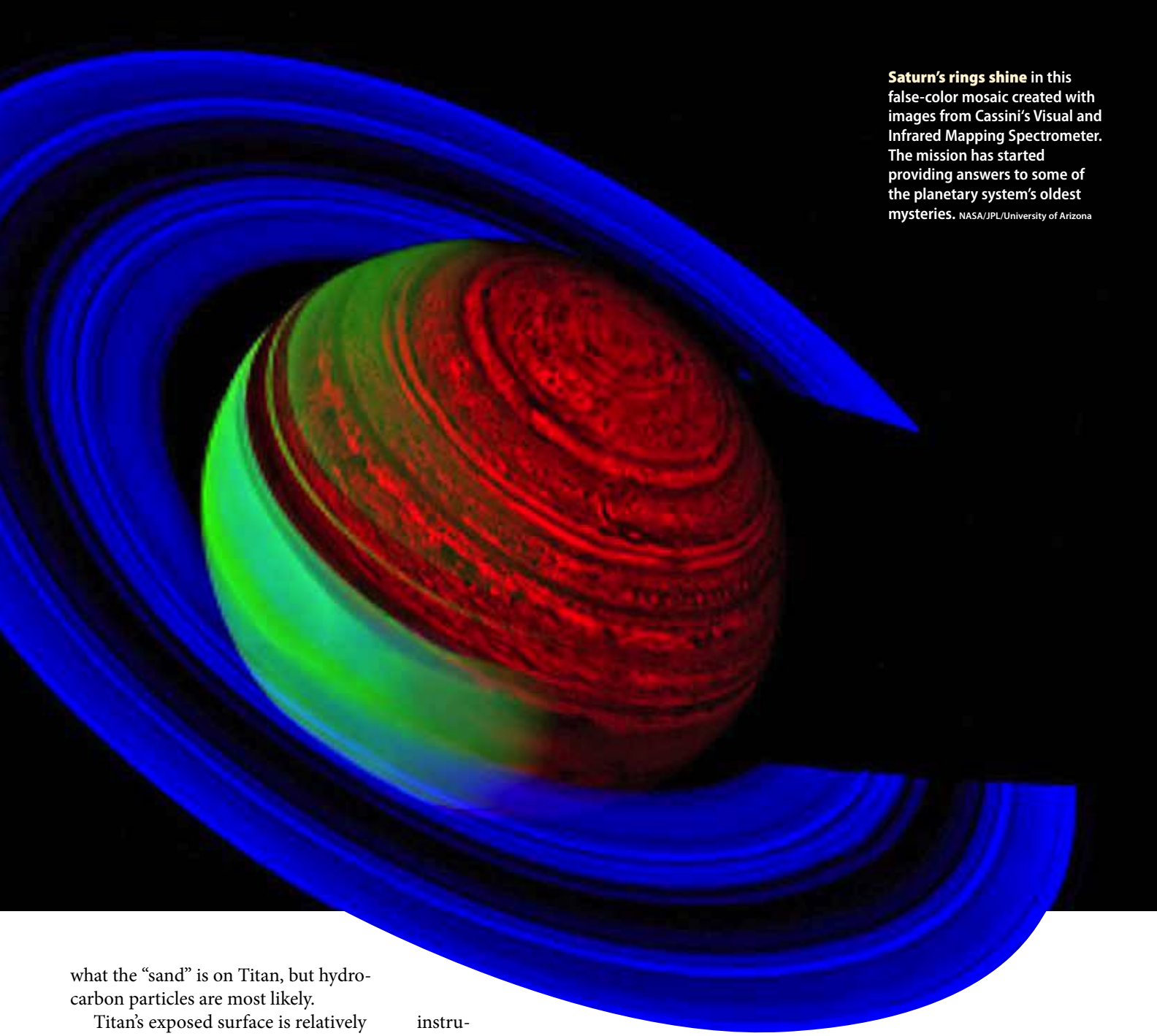


The Huygens probe descended on Saturn's biggest moon, Titan, January 14, 2005. Delivered by the Cassini spacecraft, Huygens saw fog, shorelines, and other features on Titan's surface. ESA/NASA/JPL/University of Arizona

1 Titan's earthlike surface

Before Cassini, Titan's thick atmosphere shrouded its surface, making it the largest unseen piece of real estate in the solar system. But when the Huygens probe detached from Cassini and landed on Saturn's largest moon January 14, 2005, we saw branching channels and a pebble-covered surface typical of riverbeds. The probe's measurements indicated a damp surface, and later observations by Cassini found myriad lakes filled with liquid, the first ever found outside Earth. Little doubt remains that ethane and methane flow on Titan's surface, forming rivers and lakes.

The similarities with Earth's geology don't stop there, though. Erosion and deposition — from winds as well as liquids — also play key roles on Titan. Views from orbit have shown vast dune fields in Titan's equatorial region, similar to the longitudinal-type dunes in desert climates like Namibia. We don't know



Saturn's rings shine in this false-color mosaic created with images from Cassini's Visual and Infrared Mapping Spectrometer. The mission has started providing answers to some of the planetary system's oldest mysteries. NASA/JPL/University of Arizona

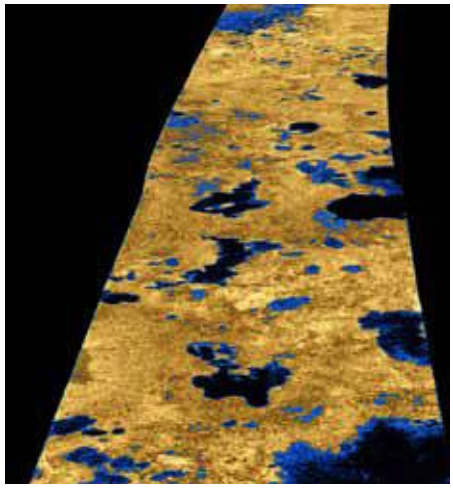
what the "sand" is on Titan, but hydrocarbon particles are most likely.

Titan's exposed surface is relatively young, like Earth's, and Cassini has found few impact craters. Mountains and ridges on Titan indicate some tectonic activity may also occur, and some evidence even suggests active volcanism (at least in the form of degassing). If this hypothesis turns out to be true, Titan will become an even more exciting candidate for future exploration.

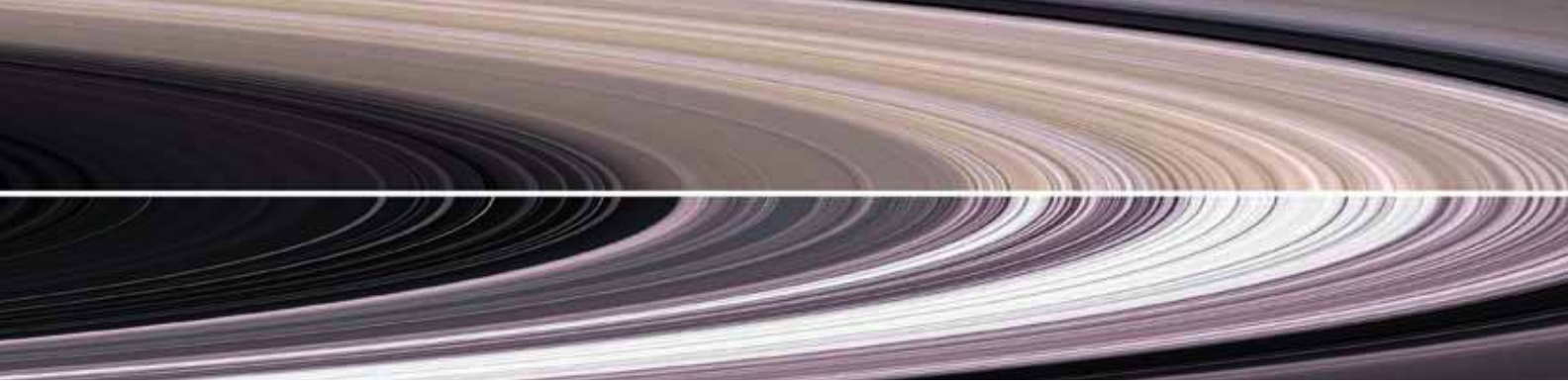
2 Titan's methane cycle

Titan's similarity with Earth doesn't stop at the surface. The moon has the second densest atmosphere of any solid body in the solar system (Venus has the densest), and Titan's atmosphere, like Earth's, is mostly nitrogen. (Cassini's instruments have detected a soup of complex hydrocarbons in Titan's atmosphere, and no free oxygen.)

Apart from the fascinating chemistry, the interaction between atmosphere and surface is the reason Titan's geology is so similar to that of Earth. Titan has clouds, rain, and weather affected by seasons. Liquids like methane and other hydro-



Liquid seas and lakes had long been theorized on Titan, but Cassini actually imaged them, providing evidence of a "methanological" cycle akin to Earth's hydrological cycle. In this false-color image, the darker blue areas represent regions of low reflectivity, likely hydrocarbon lakes. NASA/JPL/USGS



carbons evaporate from lakes and seas and feed a "methanological" cycle, much like Earth's water feeds its hydrological cycle. This is the first time we have been able to study such a phenomenon on an extraterrestrial world.

The Cassini mission's long duration even allows us to observe this cycle at work. When Cassini arrived at Saturn in 2004, during summer in the southern hemisphere, it imaged Ontarius Lacus, a lake near Titan's south pole. Moving toward equinox in August 2009 and beyond, we saw seasonal changes occurring: Ontarius Lacus shrank slightly from its size in 2004.

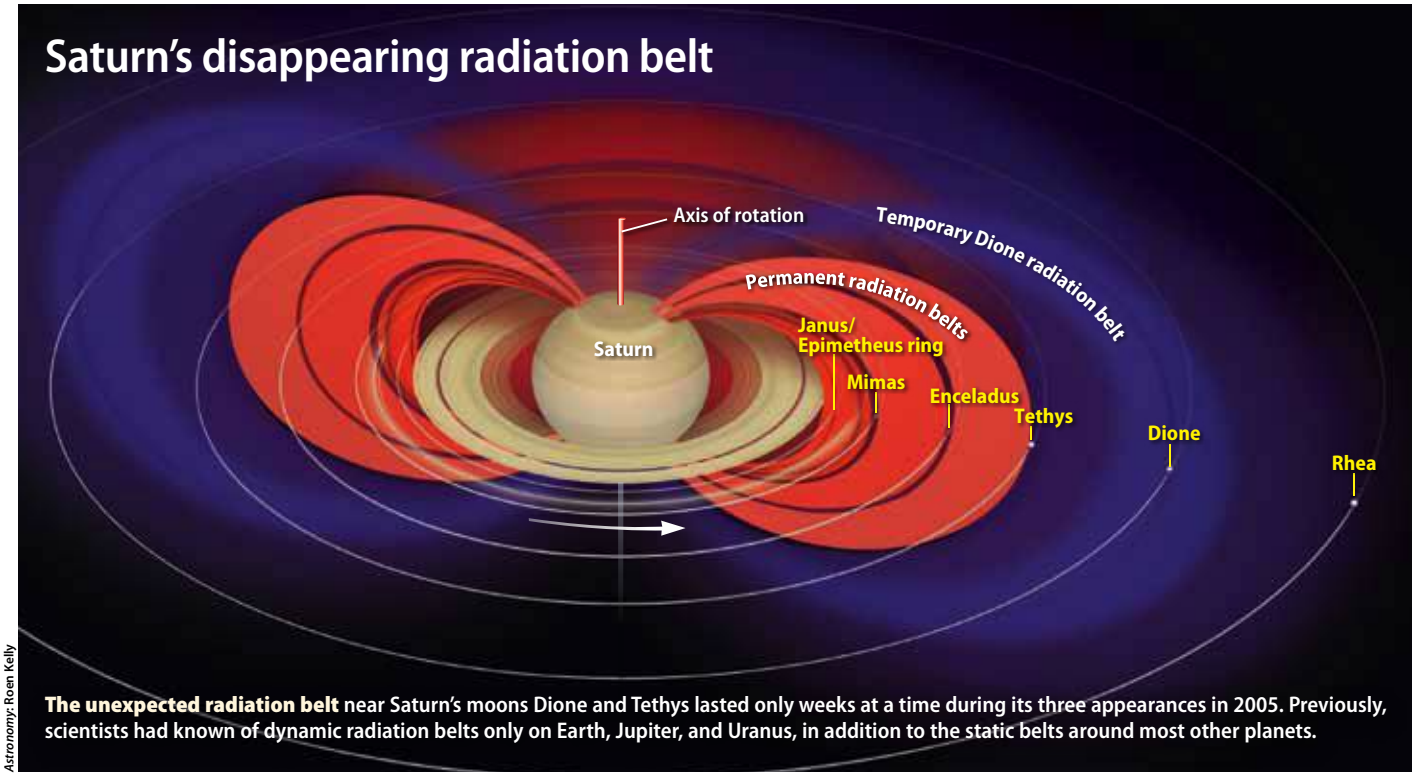
3 The Dione radiation belt

Although radiation belts like Earth's Van Allen belt exist around several planets, only Earth, Jupiter, and Uranus had previously exhibited any variations within them. Early in its mission, Cassini's Magnetospheric Imaging Instrument (MIMI) detected a surprising new radiation belt between Saturn's upper atmosphere and its D ring.

Another unexpected discovery happened later in the mission when MIMI detected sudden increases in the intensity of high-energy charged particles near the moons Dione and Tethys — about 234,000 miles (377,000 kilometers) from Saturn. These increases happened three times in 2005 as a result of solar storms that hit the magnetosphere and formed a new, temporary radiation belt, which became known as the Dione belt. The belts were short-lived, lasting only a few weeks after each of their three sudden appearances, probably because Dione and Tethys gradually absorbed the newly formed charged particles.

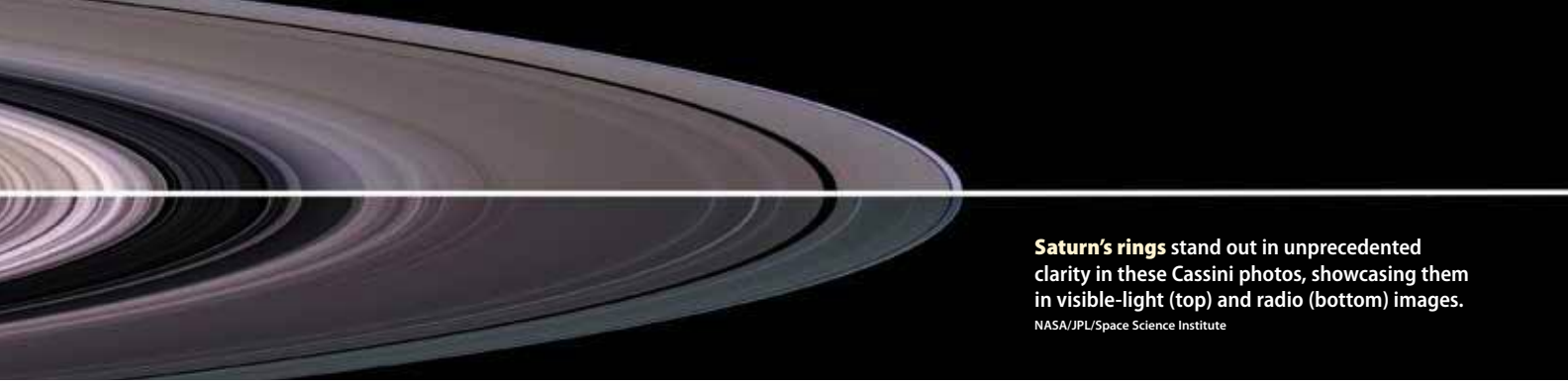
Interestingly, the other radiation belts — those closer to Saturn — show almost no variation despite years of Cassini observations. It seems a permanent radiation gap lies along Tethys' orbit, perhaps because the moon acts as a barrier against the transport of energetic particles. Current theories suggest the belts within Tethys' orbit are probably due to interactions among Saturn's rings, atmosphere, and galactic cosmic rays. (Unlike particles in the solar wind, cosmic rays have very high energies and penetrating power). If that is the case, the inner radiation belts will vary only if the local intensity of cosmic rays changes significantly.

The next few years will give Cassini more opportunities to observe how these belts behave. As we approach solar maximum, when solar activity peaks, it will be fascinating to see how the radiation belts outside the orbit of Tethys respond, and whether the Dione belt might become a more permanent, though highly variable, component of Saturn's magnetosphere.



The unexpected radiation belt near Saturn's moons Dione and Tethys lasted only weeks at a time during its three appearances in 2005. Previously, scientists had known of dynamic radiation belts only on Earth, Jupiter, and Uranus, in addition to the static belts around most other planets.

Astronomy: Roen Kelly



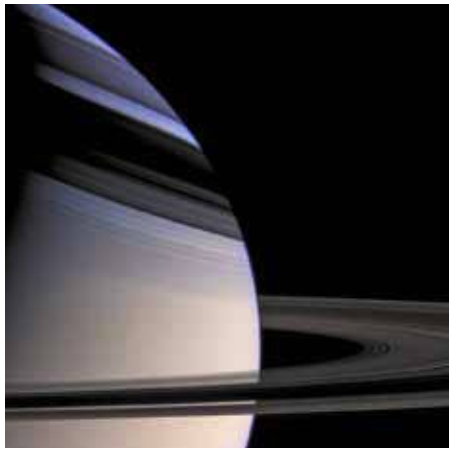
Saturn's rings stand out in unprecedented clarity in these Cassini photos, showcasing them in visible-light (top) and radio (bottom) images. NASA/JPL/Space Science Institute

4 Saturn's rings in unprecedented detail

When Cassini established its orbit around Saturn in 2004, it flew through the F and G ring gap (the faint, narrow rings located just outside the outermost of the "classical" rings, the A ring [see "Get to know Saturn's rings" on page 34]). The highest-ever resolution images of the rings come from this time, allowing scientists to glimpse such features as straw-like clumps several miles long in the A ring. Since then, Cassini has observed the evolution of the rings, finding dramatic variations not only in the decades since the Voyager missions, but also years and even weeks apart. Scientists have found (and lost) a number of objects in the F ring region, which may just be transient clumps of debris; they've even caught a nearby moon, Prometheus, stealing particles from the F ring, creating streamers and channels.

Most of the known structures in the rings result from a kind of celestial dance between the rings themselves and gravitational forces from Saturn and small moonlets embedded in the rings. These moonlets can open gaps in the ring material surrounding them, as first shown by the discovery in Voyager 2 images of the moonlet Pan (only 8.7 miles [14 km] in radius) in the Encke division. Cassini validated that finding when it discovered the tiny moonlet Daphnis (2.5 miles [4 km] in radius) in the Keeler gap. At equinox, Cassini images showed curtains of ring particles towering 2.5 miles (4 km) above the 33-foot-thick (10 meters) rings, only visible because of the long shadows they cast on the rings. The sizes of the gaps are proportional to the sizes of the moonlets, consistent with the theory that large-mass objects can create gaps in orbiting disks.

Rosaly Lopes *is a senior research scientist at NASA's Jet Propulsion Laboratory and the Cassini Radar's investigation scientist. She has written several books, including* The Volcano Adventure Guide *(Cambridge University Press, 2005).*



The blue tint of Saturn's northern hemisphere surprised astronomers when Cassini arrived in 2004. Theories currently suggest it may be due to the shadows from Saturn's vigorous ring system. NASA/JPL/Space Science Institute

5 Saturn's dynamic atmosphere

One of the most unexpected results from Cassini's arrival at Saturn was discovering that the planet's entire northern hemisphere looked different from the days of the Voyager encounters. The northern atmosphere appeared an unexpected deep blue — much like the deep, clear atmospheres of Uranus and Neptune. The likely explanation is that the shadows of the rings cooled this hemisphere down, causing the tan clouds to sink to invisible depths.

As Saturn's seasons changed from northern winter to spring, the rings' shadows moved toward the equator and Saturn's northern hemisphere lost its bluish tint, returning to its usual golden hue. At the end of Cassini's 7-year extended mission, it will be winter in the south, with the rings' shadows falling on the southern hemisphere — will it, too, turn blue with the changing seasons?

Cassini has also witnessed powerful lightning storms occurring in enormous, deep thunderstorm columns nearly as large as Earth that occasionally boil up to the visible cloud tops. Cassini's monitoring of the storms showed that they can emerge suddenly and last for weeks. In 2006, the Radio and Plasma Wave Science instrument detected the most powerful lightning storm ever seen, larger than the continental United States. Another first Cassini achieved that year was the discovery of a hurricane-like storm with a clearly defined "eye" near Saturn's south pole — the first ever seen outside Earth.

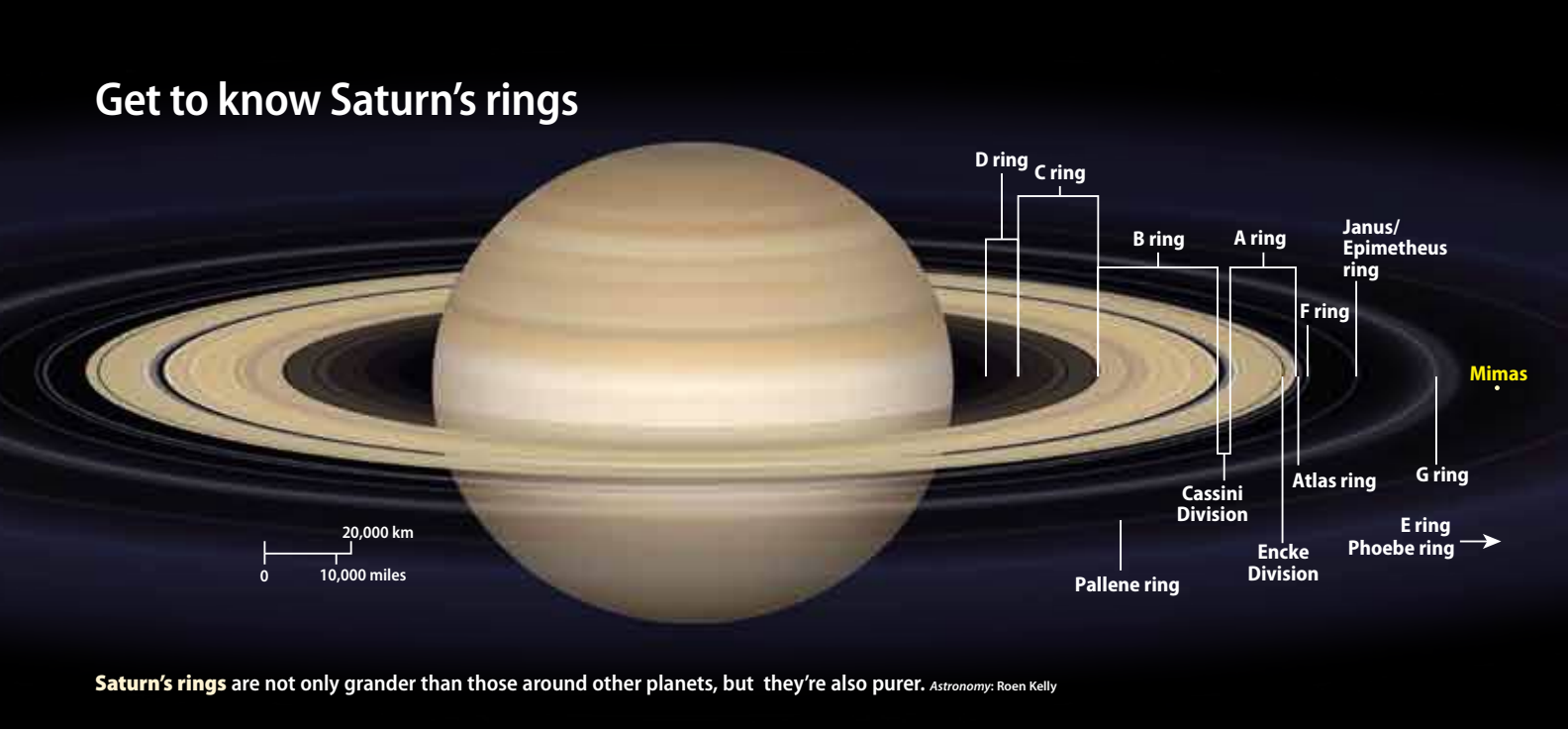
Cassini's instruments have probed the nature of the clouds associated with these thunderstorms, identifying two main types. The first are relatively bright ammonia clouds, the first source of ammonia ice ever detected on Saturn. The second are unusually dark clouds that have some carbon in their composition, produced over several years thanks to lightning generated in thunderstorms.

6 Active plumes on Enceladus

Saturn's moon Enceladus, only about 313 miles (504 km) in diameter, puzzled scientists since the two Voyager missions in the 1980s because of its location within Saturn's wispy E ring. We knew the ring had to be replenished from somewhere, and the appearance of Enceladus, with areas devoid of impact craters and an overall bright, pristine ice surface, made cryovolcanism the most likely source.

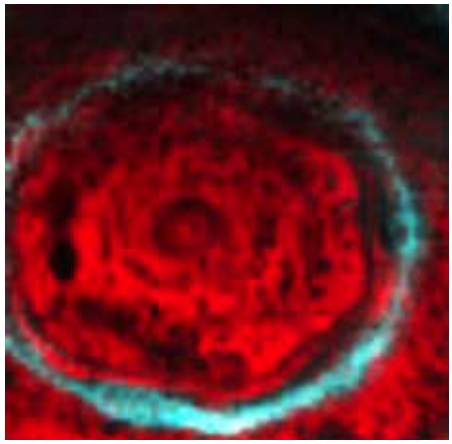
Early in its mission, Cassini captured several stunning images of Enceladus, showing its southern polar region's long, nearly parallel fractures that soon became known as "tiger stripes." Magnetic field data showed a tenuous atmosphere that implied gases occasionally escaped the tiny moon.

In 2005, Cassini obtained spectacular images of plumes shooting up hundreds of miles from the fractures near the south pole. Infrared measurements detected



Saturn's rings are not only grander than those around other planets, but they're also purer. *Astronomy*: Roen Kelly

Saturn's tiny moon Enceladus most likely replenishes the E ring with its regular plumes of spurting ice particles, water vapor, and trace organic compounds. NASA/JPL/Space Science Institute



Saturn's hexagon long puzzled scientists with its unusual regularity. In this infrared view of the north pole, it lies below the blue illumination of the planet's aurora. NASA/JPL/University of Arizona

higher temperatures coinciding with the tiger stripes, and other instruments detected water vapor in the plumes, as well as other gaseous molecules such as carbon dioxide and ammonia.

The connection between the E ring and Enceladus' plumes subsequently became well-established, and a sampling of E ring particles via Cassini's Cosmic Dust Analyzer revealed sodium, which may be coming from an ocean below the moon's icy crust. These Cassini discoveries have turned little Enceladus into a prime target for future exploration. If liquid water hides under the surface, then all the ingredients for life (as we know it) are there: liquid water, molecular building blocks, and heat.

7 Saturn's mysterious hexagon

The north polar hexagon first emerged in Voyager images about 30 years ago, but it's thanks to Cassini that we now know how persistent and intriguing this feature is. When Cassini arrived in 2004, the north polar regions of Saturn were in darkness, but images taken by Cassini's Visible and Infrared Mapping Spectrometer showed the hexagon was still there, having survived at least 3 decades. Unlike other cloud and storm features, the hexagon is nearly stationary. We know that it extends deep into the atmosphere and rotates with a period of 10 hours, 39 minutes, and 24 seconds, the same as Saturn's radio emissions — presumably equal to the rotation period of the planet's interior. Each of the straight sides of the hexagon is nearly 8,700 miles (14,000 km) long.

As Saturn's north polar region came into daylight after the equinox, Cassini's camera imaged the hexagon in greater detail, showing curlicues, circles, and streamers, as well as a dark spot that changed location, and a polar vortex inside the hexagon. We are, however, still unsure what causes the pattern and why it is so persistent.

Most scientists think it's the result of some standing-wave pattern in the atmosphere, and some have produced similar features in laboratories using spinning buckets of fluids modeling Saturn's atmosphere. As more detail comes out in future images, atmospheric scientists hope they will be able to solve the mystery. What's clear is that Saturn has a bizarre and unique weather system at its north pole, exactly the kind of findings that advance our knowledge of planetary science.

8 Rusty rings?

Saturn's rings are different from those around the other giant planets not only because they are larger and more spectacular, but also because of the purity of their ice particles. Other ring systems are "dirtier," with more rocks and carbon-rich organic materials. Saturn's A and B ring particles are nearly completely water ice, yet they appear reddish. Earlier theories suggested that the hue resulted from

organic tholins (reddish compounds irradiated with ultraviolet light), which color Titan's ruddy atmosphere, but Cassini didn't find any. It was also a logical assumption that some ices and organic materials (such as ammonia and carbon dioxide) seen on certain moons would be present in the rings, but Cassini found none of these either.

Cassini did show that the A and B rings are much redder than any of Saturn's moons, but the material responsible for this absorption in the ultraviolet spectrum is still a puzzle.

The surprising discovery of an oxygen atmosphere around some rings inspired the idea of "rusty rings," with two candidate materials under discussion: small clusters of carbon rings and nanoparticles of hematite (the form of iron oxide, or rust, that gives Mars its red color). Perhaps Cassini will give us the answer — an important one because it would provide important clues to the rings' formation and evolution.

9 Phoebe: a captured world

As Cassini approached Saturn in 2004, it flew by the tiny moon Phoebe, long considered "different" among Saturn's satellites: Its retrograde orbit implies that Saturn's gravity captured it, rather than it forming from the same matter as the other moons. The question before Cassini was to learn whether Phoebe was a captured asteroid, Kuiper Belt object (bodies from beyond Neptune's orbit, such as Pluto and Eris), or Centaur (bodies orbiting between Saturn and Uranus with characteristics of asteroids and comets).

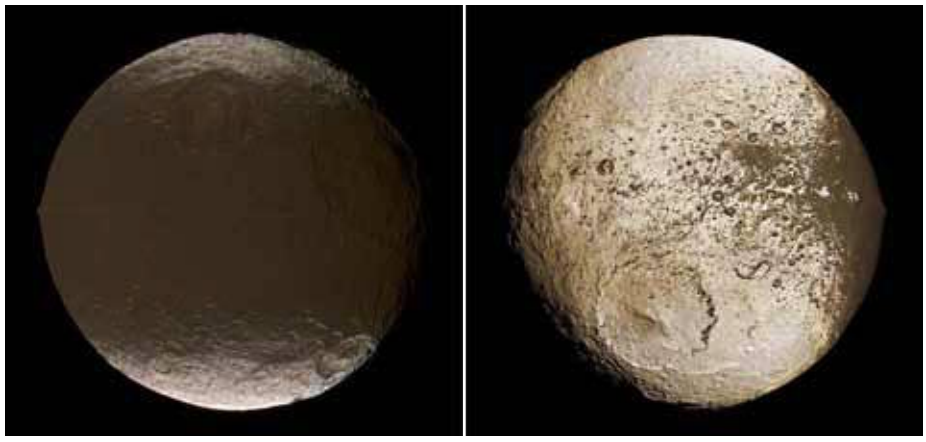
NASA/JPL/Space Science Institute

Little Phoebe, unique among Saturn's larger moons for its retrograde orbit, is likely a Kuiper Belt object that fell victim to Saturn's gravity.

Cassini images showed Phoebe to be a heavily cratered ancient world, with large landslides revealing bright water ice and a patchy clustering of silicate and organic material. Spectral analysis in the infrared showed that Phoebe's surface is rough and dusty, suggesting a history of outgassing. Together with the surface ice, the data tell us that Phoebe must have formed in the outer solar system before falling victim to Saturn's gravity. Cassini detected no volatile emissions consistent with comet-like activity (such as that detected on the Centaur Chiron), so we feel confident establishing Phoebe as a Kuiper Belt object — one we are able to study close up.

10 Iapetus: the "two-faced" moon

The moon Iapetus has two strikingly different faces: the leading side (facing the direction of motion) is about 10 times darker than the trailing side. When Cassini flew by Iapetus in 2004, its camera revealed another puzzling characteristic: a narrow equatorial ridge of bright material, in places more than 12 miles (19 km) high, making the moon look like a walnut. The ridge's origin remains unknown, though some suggest it's a remnant of the oblate shape (like a squashed ball) the moon had in its younger years, when it rotated more rapidly.



NASA/JPL/Space Science Institute

The mystery of two-faced Iapetus, a distinct difference in brightness between the moon's leading (forward-facing) side (left) and its trailing side, is likely due to the gradual migration of water ice on a global scale, leaving one side cooler and shinier and the other darker and hotter.

Cassini was, however, able to shed light onto the old mystery of the two faces. It detected similarities in the surface composition of Iapetus and Phoebe and determined that the dark color on Iapetus is due to a thin layer of material only a few inches thick. Darker areas are warmer, so the scientific consensus is that the dark material is residue left over from the sublimation of water ice into gas. A cycle thus took place: The darkened ice absorbed more sunlight, sublimed, and recondensed as bright frost on the lighter (and colder) surface of the poles and trailing hemisphere. Over time, the contrast became more pronounced and eventually left the dark side with no exposed ice.

Where did the dark material come from? A possible connection between Iapetus and Phoebe had already gained support when, in October 2009, the Spitzer Space Telescope discovered a giant ring around Saturn: the "Phoebe ring," the largest and most distant ring from its parent body yet known. The Phoebe ring's particles may have originated from micrometeoroid impacts on Phoebe. Over many thousands of years, sunlight pushed the particles inward, striking Iapetus. It seems that Phoebe, the interloper from the outer solar system, slowly "painted" one of Iapetus' faces.

Although many puzzles remain, it's clear that the Saturn system is more complex than anyone ever imagined. Cassini has revealed an exceedingly dynamic place, full of unique phenomena.

Watch a video of Huygens' descent onto Titan at www.Astronomy.com/toc.

The Sky this Month

Martin Ratcliffe and Alister Ling describe the solar system's changing landscape as it appears in Earth's sky.

November 2010

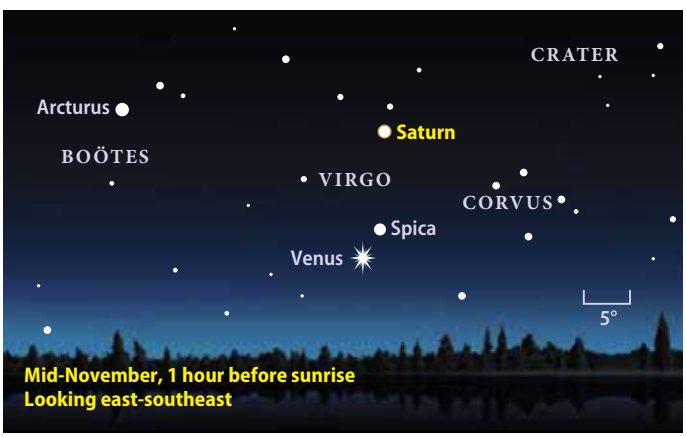
Saturn and its rings return

Saturn's rings tilt more this month than they have in nearly 3 years, making for a stunning view of the ringed planet through any telescope. NASA/ESA/Hubble Heritage Team (STScI/AURA)

36 Saturn's rings open up
41 Meteor watch
41 Rising Moon
42 When to view the planets
42 Io and Europa reappear together
42 Comet search
43 Locating asteroids
43 Mercury and Mars meet

Visible to the naked eye
Visible with binoculars
Visible with a telescope

Darkness falls early in late autumn, and that benefits observers who want to view Jupiter. The king of the planets continues its evening reign throughout November. Simply look south after sunset and it will pop out of the darkening sky. Mercury and Mars lie low in the southwest in mid-November, but they'll be tricky to catch in the twilight. Observers will have an easier time seeing Uranus through binoculars and Neptune through a telescope.



Saturn returns to prominence in the morning sky, where it climbs noticeably higher from week to week. *Astronomy*: Roen Kelly

You'll have to wait until the wee hours to see another bright planet. Venus rises quickly out of the Sun's glare following its late October inferior conjunction and appears dazzling for most of November. Saturn appears dimmer than Venus, but the ringed planet lies significantly higher in the predawn sky.

Let's begin our November tour with a look at **Jupiter**. Within 30 minutes of sunset, you should be able to spot the bright planet about 30° high in the southeast. It's a spectacular object in the south by 8 P.M. local time, when it stands halfway to the zenith for observers at mid-northern latitudes. It then lies below the Great Square of Pegasus and the Circlet asterism in Pisces.

Jupiter shines at magnitude –2.8 in early November and fades slightly to magnitude –2.6 by month's end. A waxing gibbous Moon stands 8° northwest of Jupiter November 15. Although Jupiter is now a couple of months past its best, its prominent position in the early evening sky will get more people to notice it.

For those with telescopes, Jupiter's disk shrinks nearly 10 percent this month. The giant planet spans 47" November 1 and 43" by the 30th. Still, that's plenty big enough for even small scopes to show some detail. The planet's South Equatorial Belt faded away early this Jupiter observing season. It might revive this autumn, but it could remain

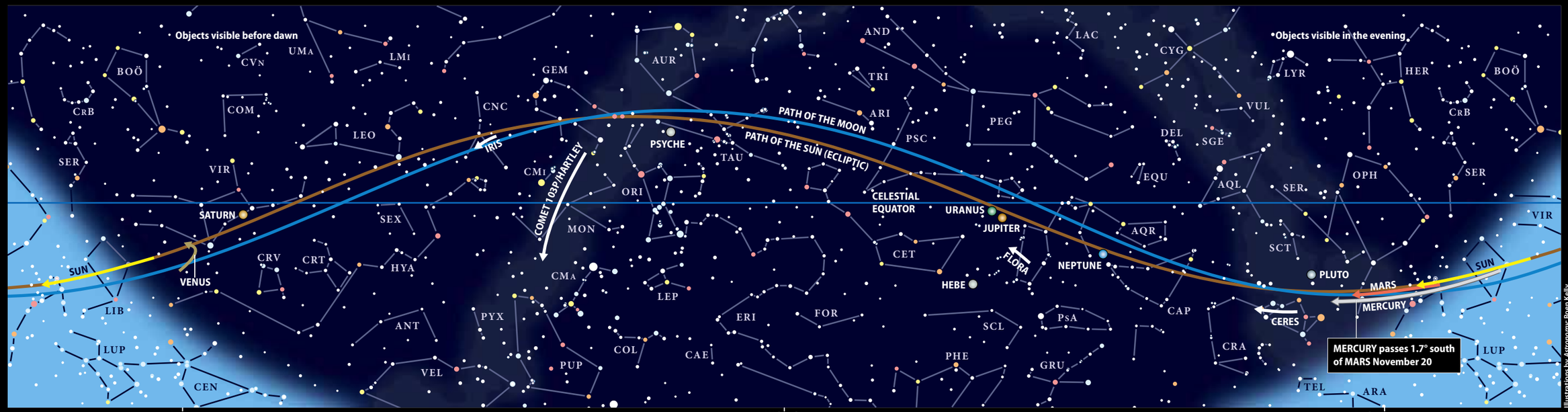
— *Continued on page 41*

Planets in November 2010

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine

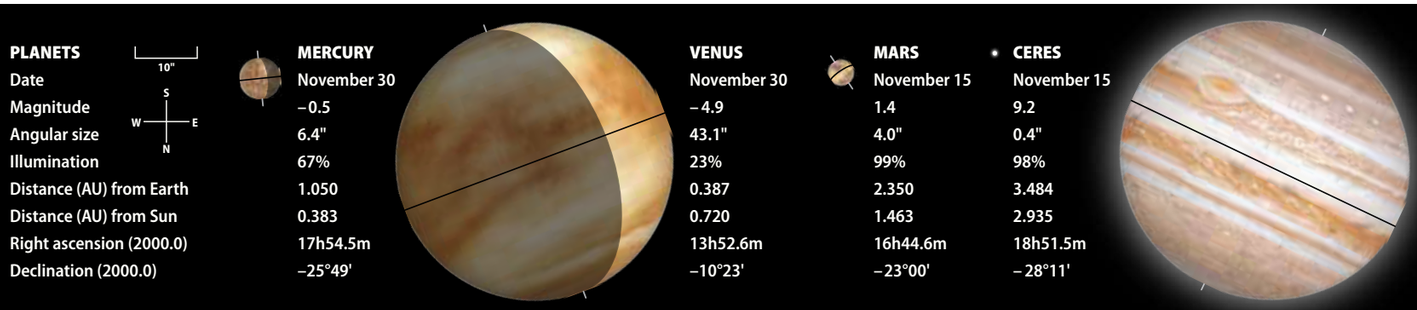
Path of the planets



MOON PHASES

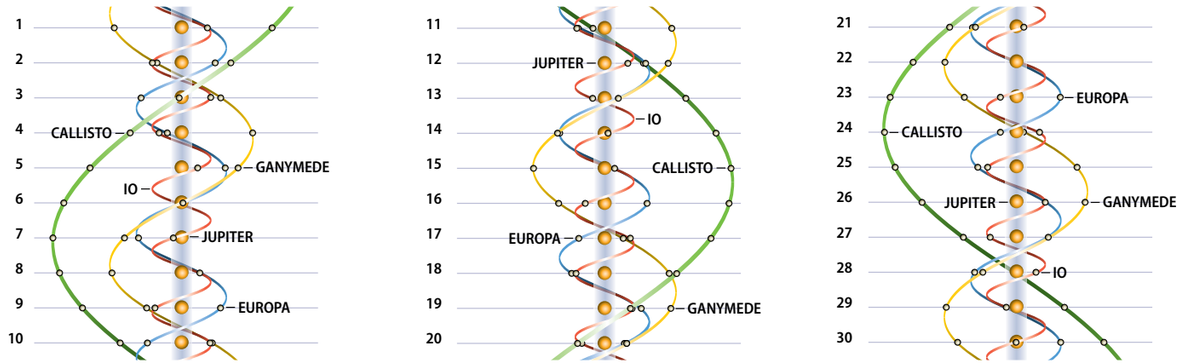
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to distance from Earth and are shown at 0h Universal Time.

PLANETS	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	November 30	November 30	November 15	November 15	November 15	November 15	November 15	November 15	November 15
Magnitude	–0.5	–4.9	1.4	9.2	–2.7	0.9	5.8	7.9	14.1
Angular size	6.4"	43.1"	4.0"	0.4"	45.1"	16.1"	3.6"	2.3"	0.1"
Illumination	67%	23%	99%	98%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.050	0.387	2.350	3.484	4.370	10.313	19.516	29.940	32.665
Distance (AU) from Sun	0.383	0.720	1.463	2.935	4.953	9.571	20.091	30.015	31.930
Right ascension (2000.0)	17h54.5m	13h52.6m	16h44.6m	18h51.5m	23h37.9m	12h50.8m	23h49.1m	21h52.8m	18h15.1m
Declination (2000.0)	–25°49'	–10°23'	–23°00'	–28°11'	–3°59'	–3°01'	–2°01'	–13°23'	–18°46'



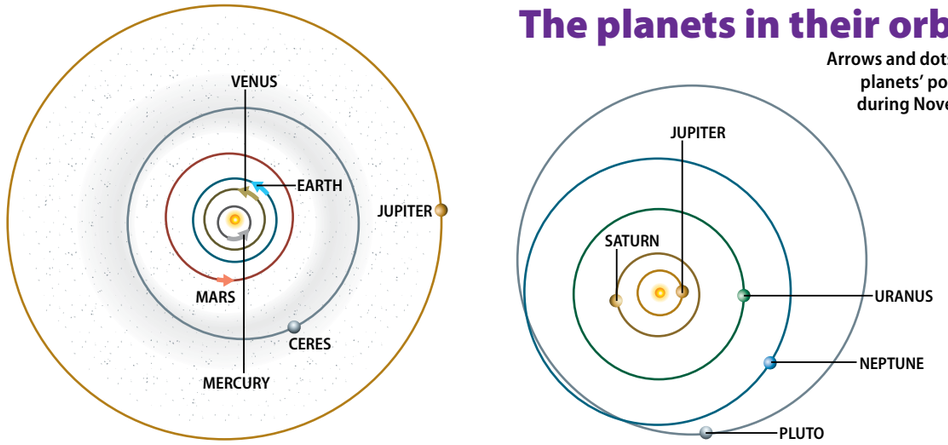
Jupiter's moons

Dots display positions of Galilean satellites at 10 P.M. EST on the date shown.
South is at the top to match the view through a telescope.



The planets in their orbits

Arrows and dots show planets' positions during November.



StarDome

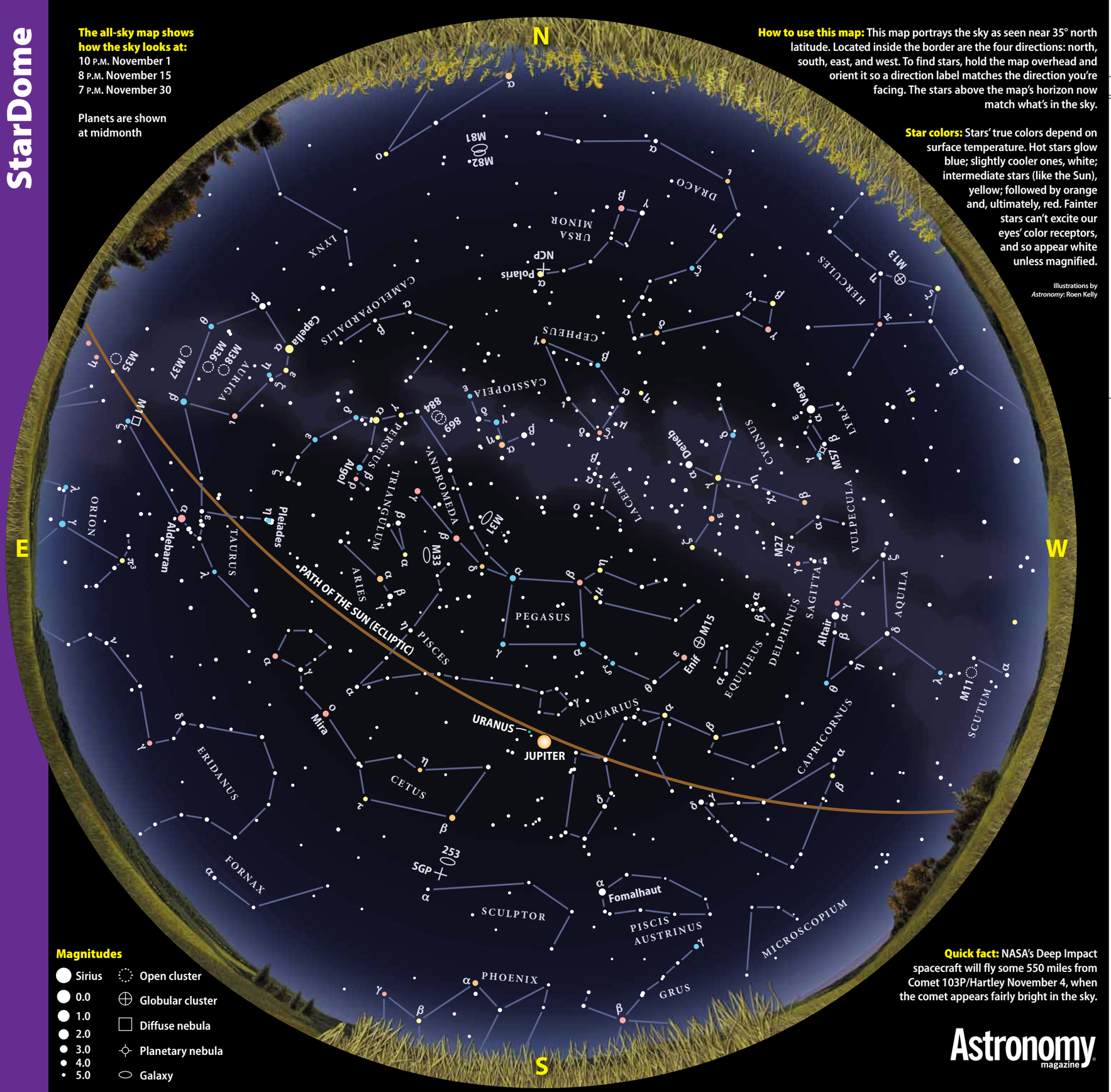
The all-sky map shows how the sky looks at:
10 P.M. November 1
8 P.M. November 15
7 P.M. November 30

Planets are shown at midmonth

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Star colors: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

Illustrations by *Astronomy*: Roen Kelly



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Quick fact: NASA's Deep Impact spacecraft will fly some 550 miles from Comet 103P/Hartley November 4, when the comet appears fairly bright in the sky.

Astronomy magazine

November 2010

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Calendar of events

1 The Moon passes 0.7° north of asteroid Juno, 8 P.M. EDT

3 The Moon is at perigee (226,298 miles from Earth), 1:25 P.M. EDT

4 The Moon passes 8° south of Saturn, 2 A.M. EDT

6 New Moon occurs at 12:52 A.M. EDT

7 Neptune is stationary, 3 A.M. EST

The Moon passes 1.6° south of Mars, 5 P.M. EST

9 Asteroid Vesta is in conjunction with the Sun, 7 P.M. EST

Mars passes 4° north of Antares, 11 P.M. EST

13 First Quarter Moon occurs at 11:39 A.M. EST

14 The Moon passes 5° north of Neptune, 1 A.M. EST

15 Mercury passes 2° north of Antares, 6 A.M. EST

The Moon is at apogee (251,426 miles from Earth), 6:45 A.M. EST

16 The Moon passes 7° north of Jupiter, 11 A.M. EST

Venus is stationary, 11 A.M. EST

The Moon passes 6° north of Uranus, 5 P.M. EST

17 Leonid meteor shower peaks

19 Jupiter is stationary, 1 A.M. EST

Special observing date

20 Mercury passes 1.7° south of Mars in the evening sky, the two planets' closest approach of 2010.

21 Full Moon occurs at 12:27 P.M. EST

28 Last Quarter Moon occurs at 3:36 P.M. EST

29 The Moon passes 0.5° south of asteroid Juno, 6 P.M. EST

30 The Moon is at perigee (229,553 miles from Earth), 1:56 P.M. EST

See tonight's sky in Astronomy.com's STARDOME

— *Continued from page 36*
AWOL for a year or more. Because such revivals have been dramatic in the past, it pays to make Jupiter a part of your observing routine.

Jupiter's slow westward trek against the background stars, called retrograde motion, comes to a halt November 19. Although Jupiter appears to stop in this sense, its moons do not. Their constant orbital motion provides observers with plenty of eclipses, transits, and occultations.

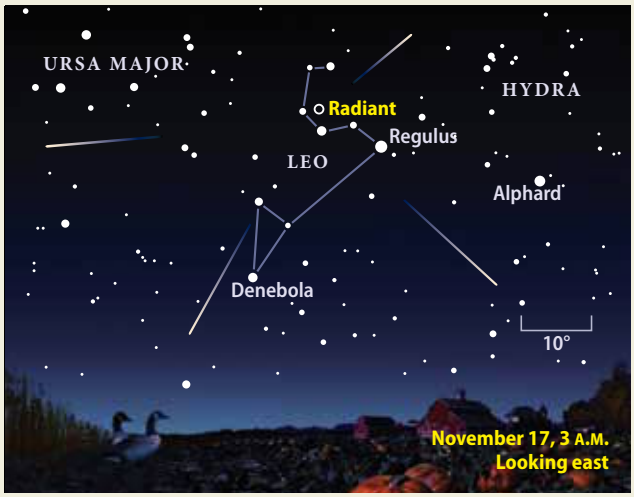
The current geometry of the Sun, Earth, and Jupiter means that a moon exiting Jupiter's shadow does so on the planet's eastern side (to the right when viewed through an inverting telescope). During such an eclipse, a moon goes from invisibility to full brightness in just a few minutes. The night of November 15/16 provides two excellent examples: Io pops out of Jupiter's shadow at 12:05 A.M. EST; Europa follows 53 minutes later. These times mark the middle of the events, so start viewing a little earlier.

An even more spectacular dual eclipse reappearance occurs the evening of November 1, when Io and Europa pop into view just a few arcseconds apart. Io reappears first, at 9:14 P.M. EDT. Less than 30 minutes later, at 9:40 P.M. EDT, the drama intensifies when Europa appears 4" to Io's northeast. Keep watch for the next hour as the two moons close to within 2" of each other.

When either Io, Europa, or Ganymede passes in front of Jupiter, backyard observers can witness the moon's disk crossing the planet followed by the moon's shadow. (The dark shadow always stands out better against the light-colored cloud tops of Jupiter's atmosphere.) For North American viewers, one of the best such events occurs November 7/8. Io begins to transit Jupiter's disk at 9:38 P.M. EST; 64 minutes later, the moon's dark shadow follows. Both the disk and the shadow take about 135 minutes to cross Jupiter's girth.

Martin Ratcliffe *provides professional planetarium development for Sky-Skan, Inc., in Nashua, New Hampshire. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

Meteor watch



Leonid meteors rain down in mid-November, although a waxing gibbous Moon makes conditions less than ideal. *Astronomy:* Roen Kelly

Autumn's Lion delivers a muted roar

The annual Leonid meteor shower returns between November 10 and 23. Although it occasionally puts on a great show, astronomers expect a more typical display this year. At the shower's peak before dawn November 17, observers under a dark sky can expect to see around 20 meteors per hour radiating from the constellation Leo the Lion.

Full Moon arrives November 21, so moonlight will interfere with Leonid viewing until after midnight. The best time to watch on the 17th comes once the Moon sets around 3 A.M. local time. Observers sometimes see a brief increase in meteors when Earth crosses the orbital path of the shower's parent comet, 55P/Tempel-Tuttle. However, this occurs after daybreak in North America.

The Taurid meteor shower peaks during November's first 2 weeks. Viewers under a dark sky can expect to see around 5 meteors per hour throughout this period. The streaks of light emanate from two radiants, both within the borders of Taurus the Bull, located some 8° apart.

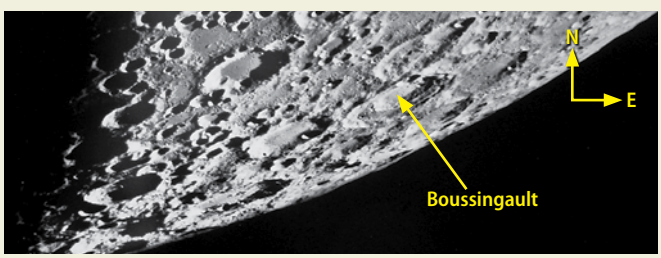
Rising Moon

Craters nested one inside the other

It's easy to find relatively small craters inside bigger ones or two side-by-side craters of nearly equal size — they're everywhere on the Moon's face. But where can you find one that fits nicely inside another? The best example is Boussingault, in the far southeastern corner of the Moon. This region remains visible from November 10 to a few nights after Full Moon on the 21st.

At first glance, you might think this is a terraced feature, where the crater's sides slumped inward sometime after the impact that excavated the large hole. But after a few moments, you should notice that this crater has a distinctly different appearance. Terraces don't have raised rims like the inner Boussingault A.

Thanks to Boussingault's far southern latitude, shadows hang around for many days and keep the crater's double nature distinct from the hundreds of other features in these rough highlands. You won't find a central peak inside this crater. The original one got wiped out by the second impact; then lava pooled up from below to cover the mountain top.



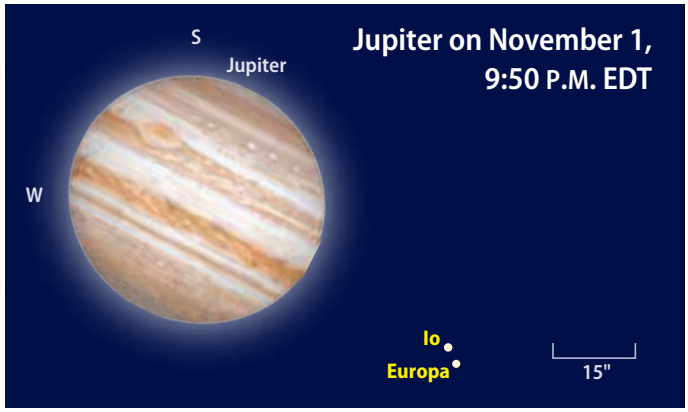
The double crater Boussingault beckons observers to the Moon's southeastern limb throughout mid-November. *Consolidated Lunar Atlas*/UA/LPL

Boussingault K, a younger, sharp-edged small crater that adorns the big crater's northern edge, reduces the chance of your getting lost. An even smaller crater chips the southern flank.

Compare what you see through a telescope to the picture above. You can see "beyond" this photo's limb because the Moon lies well above the ecliptic in mid-November, giving us a chance to see over the horizon and a bit onto the Moon's farside.

When to view **the planets**

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (southwest)	Jupiter (southwest)	Venus (southeast)
Mars (southwest)	Uranus (southwest)	Saturn (southeast)
Jupiter (southeast)		
Uranus (southeast)		
Neptune (south)		



Galilean moons Io and Europa exit Jupiter's shadow and return to view near each other the evening of November 1. *Astronomy*: Roen Kelly

North Americans can expect repeat performances from Io November 14/15 (disk transit begins at 11:28 P.M. EST; shadow transit at 12:38 A.M. EST) and November 23 (disk transit begins at 7:47 P.M. EST; shadow transit at 9:03 P.M. EST). The best-timed Europa transit is November 24 starting at 5:52 P.M. EST with the shadow following at 8:22 P.M. EST. Because Europa orbits farther from Jupiter than Io, the transits take a little longer (about 25 minutes more) to complete.

While you are in Jupiter's vicinity, take a moment to track down **Uranus**. It lies about 3° northeast of Jupiter all month. At magnitude 5.8, Uranus glows just bright enough to glimpse with naked eyes under a dark sky. Binoculars significantly enhance the view. Through a telescope at magnification 100x, you can see the distant planet's 3.6"-diameter disk, which glows with a distinctive blue-green hue.

Uranus' slow westward motion relative to the background stars loses steam in November. It nearly comes to a stop by month's end, when the planet lies 42' north of 5.5-magnitude star 20 Piscium.

Before the sky darkens fully, try to spot **Mercury** and **Mars** low in the southwest. The best time to see the two together is November 20, when Mercury passes 1.7° south of Mars. Mercury then shines at magnitude –0.4, some 5 times brighter than Mars, but both are a challenge because of their low altitudes. Mercury stands just 3° above the horizon 30 minutes after sunset; Mars appears 1° higher. Try scanning the area through binoculars to pick up the planets.

After this conjunction, Mars descends deeper into the twilight and disappears from view around month's end. Mercury climbs higher, however, and becomes more conspicuous. On November 30, it appears 6° high in the southwest 30 minutes after sunset. A telescope then shows a disk 6" across and two-thirds illuminated.

Wait until the sky darkens fully before setting your sights on **Neptune**. The distant planet lies in northeastern Capricornus, a region that appears due south once twilight fades away. Neptune

Comet search

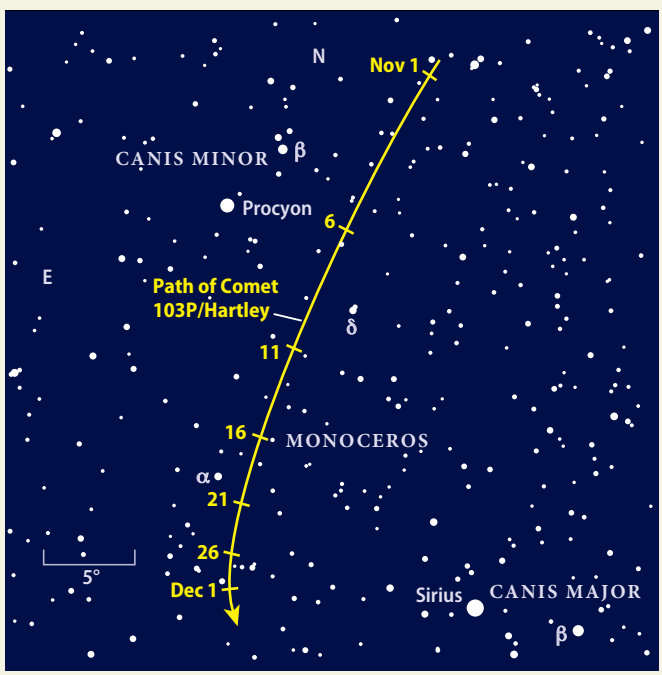
Hartley puts on a really good show

The best comet of 2010 — arguably the best nighttime celestial event of the year — is near its peak in November's evening sky. Step into your backyard or head to a city park with binoculars, and you'll be able to spot Comet 103P/Hartley. The comet should look like a short sword floating within the rough confines of the bright Winter Triangle, comprising Betelgeuse, Procyon, and Sirius.

The comet's head forms the sword's handle while the upward-pointing tail creates the blade. Under a dark sky, the 5th-magnitude comet should be a delightful sight with unaided eyes. A small telescope reveals a long curving dust tail that gradually fades against the background Milky Way. A larger scope also might reveal the head's greenish color and a bluish hue to the straight gas tail.

A comet's dust typically spreads out into a broad, fan-shaped tail as pressure from sunlight gently nudges the tiny dust particles away from the Sun. The same holds true for Comet 103P/Hartley. But in this comet's case, the tail turned edge-on to our line of sight in late October. Like a sheet of paper turned edge-on, Hartley's dust tail then appeared sharp and narrow. As the comet slips below Earth's orbital plane in early November, the fan spreads out again and the gas tail re-emerges from behind the dust tail.

A comet's gas and dust typically keeps its nucleus hidden from view. Thanks to NASA, this will not be the case with 103P/Hartley. The former Deep Impact spacecraft has been rechristened as EPOXI and will fly within about 550 miles of 103P/Hartley November 4.



Autumn's premier comet, 103P/Hartley, should glow bright enough to glimpse with naked eyes under a dark sky. *Astronomy*: Roen Kelly

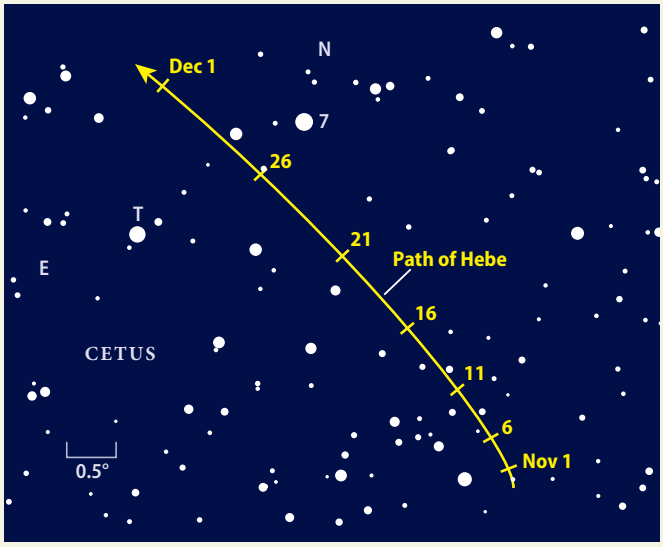
Hebe sails autumn's celestial sea

A great way to see the solar system in motion is to track an asteroid. This month, the distant stars provide steady lanterns to guide our course and chart the graceful arc of asteroid 6 Hebe as it crosses the ocean of the celestial whale, Cetus.

Look toward the south in midevening and locate the twinkling yellow star Beta (β) Ceti. Normally, 2nd-magnitude Beta ranks second in the autumn sky to 1st-magnitude Fomalhaut to its lower right. But this year, blazing Jupiter upstages both of them. Look for Beta Ceti about 20° to Jupiter's lower left.

Slide your scope west of Beta to a trio of 4th- and 5th-magnitude stars, which includes 7 Ceti, then head a few degrees south to find Hebe. Remember that your finder scope may show things upside down or flipped right to left compared with the finder chart at right. From November 12 to 15, Hebe shares a field with two stars. The 120-mile-wide asteroid glows at magnitude 8.6, making it slightly fainter than either star. Sketch the three dots on paper and return a night or two later. Hebe will be the one that moved relative to the others. On November 26, the asteroid passes 1° southeast of 7 Ceti.

Karl Hencke discovered Hebe July 1, 1847. Astronomers named it after the Greek goddess who bears the cup of ambrosia.



Asteroid Hebe glows between 8th and 9th magnitude this month as it glides through the southwestern part of Cetus. You can identify it by its motion relative to the background stars. *Astronomy*: Roen Kelly

glows at magnitude 7.9, bright enough to show up through binoculars, although a telescope makes identification easier. A scope reveals the planet's 2.3"-diameter disk and blue-gray color.

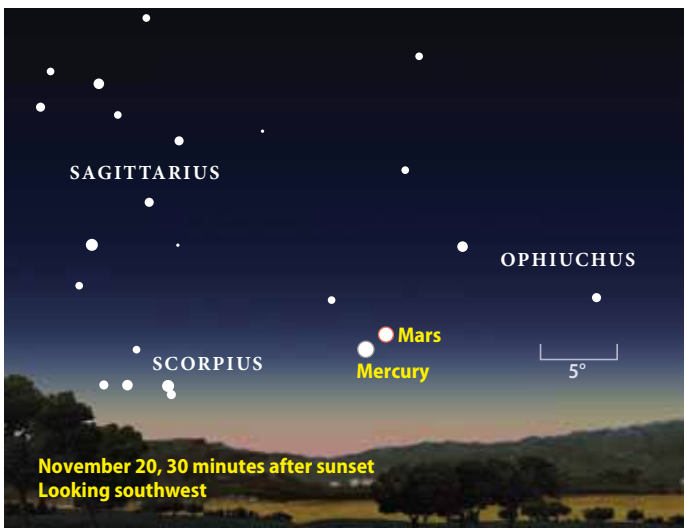
To track down Neptune, first locate Delta (δ) Capricorni. This 3rd-magnitude star marks the northeastern extremity of the Sea Goat. Neptune lies some 3° northeast of Delta and within 0.2° of 5th-magnitude Mu (μ) Cap. You'll have a hard time noticing Neptune's motion relative to Mu during November's first 2 weeks, but it picks up the pace after that.

You can find **Saturn** low in the east as twilight begins in early November. With each passing day, the ringed planet rises earlier and climbs higher before dawn paints the sky. By month's end, it's 30° high when twilight commences.

Saturn's increasing altitude translates into improving views through a telescope. The last time we saw the planet so clearly, in the evening sky early this summer, the rings tilted only 2° to our line of sight. It was hard to make out much detail. No longer — the rings now tilt 9° and present a fine view of their northern face. The Cassini Division that separates the two brightest rings stands out better than it has in years. Saturn's ring system spans 37" in mid-November, more than double the planet's equatorial diameter of 16".

Saturn lies in Virgo throughout November. It begins the month 1° from 3rd-magnitude Gamma (γ) Virginis and ends the month roughly midway between Gamma and 4th-magnitude Theta (θ) Vir. Saturn shines at magnitude 0.9, far brighter than either star and even beating Spica, Virgo's brightest star, by 0.1 magnitude.

Despite Saturn's allure, **Venus** quickly competes for your morning attention. Venus passed between the Sun and Earth, a configuration called inferior conjunction, in late October. But like Saturn, it quickly rises out of the morning twilight. Look for it toward the end of November's first week when it pops up just below Spica. The planet shines so brightly, at magnitude –4.4, that you won't mistake it for any other celestial body.



Mercury and Mars join each other low in the southwestern sky shortly after the Sun goes down November 20. *Astronomy*: Roen Kelly

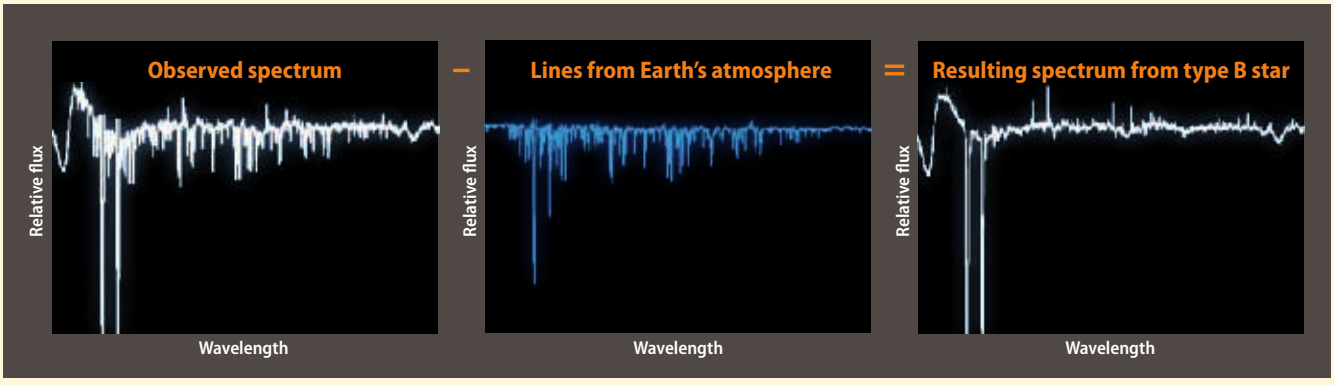
Venus lies 6° below Spica November 7. It might appear that Venus' rapid climb in the morning sky will allow it to catch Spica, but it never quite gets there. The closest the two come is 4° during November's third week.

November is a great time to view Venus through a telescope because the planet's appearance changes dramatically. On the 7th, Venus' disk spans 59" and shows a slender crescent just 3 percent illuminated. But the planet moves quickly away from Earth. This causes Venus' angular diameter to shrink and its phase to wax. On November 30, the planet displays a 43"-diameter disk that's 23 percent lit.

Ask Astro

Astronomy*'s experts from around the globe answer your cosmic questions.*

Sorting out a spectrum



A spectrum obtained from a ground-based telescope incorporates spectral lines from both the studied object and Earth's atmosphere. Astronomers have a way of separating the two, which is good news because a spectrum contains a lot of important information. *Astronomy:* Roen Kelly, after Erin Wood

Q: How do you distinguish between absorption lines that originate in a distant astronomical object and those from Earth's atmosphere? — **David Loh,** Singapore

A: The strength of the absorption lines from Earth's atmosphere (called telluric lines) depends on the air mass in the line of sight toward a distant object. Therefore, it depends on the object's position in the sky — the higher the object is above the horizon, the weaker the telluric lines become. In contrast, the strength of the intrinsic lines that the object produces remains unchanged when in different locations in the sky. But they may still change on different timescales due to the object's physical processes, like if it has any motion.

Another difference is that various **physical mechanisms broaden the intrinsic absorption lines**. The most important is that the random motions of the absorbing atoms cause "Doppler broadening." Larger motions within the object, such as turbulence and rotation, further broaden the lines. **In contrast, telluric lines are sharp and narrow:** Earth's atmosphere is cooler, and thus Doppler broadening is typically smaller.

We can spot these two differences even before we associate the lines with an absorbing or emitting atom, ion, or molecule. **Once we identify the wavelength, we notice another difference between telluric and intrinsic lines: Telluric lines appear essentially at their laboratory wavelengths (although vertical motions within Earth's atmosphere can cause small departures), while the intrinsic lines are Doppler shifted due to Earth's movement around the Sun and a relative motion between the Sun and the observed object.**

Telluric lines also pertain to only a few species in Earth's atmosphere — namely oxygen, ozone, water vapor, carbon dioxide, and methane. If we know the basic physical properties of the observed object (such as temperature), we know that such lines cannot possibly originate in the object if its temperature is high (because then the molecules break up and the atoms are typically ionized). — **Ivan Hubeny,** University of Arizona, Tucson

A TELESCOPIC GUIDELINE

Q: What does "maximum usable" magnification mean? — **Jon Owen,** Tampa, Florida

A: "Maximum usable" magnification is a rough number someone about 30 years ago invented to give observers an idea of the upper magnification limit they could expect from their telescope. I have most often seen it given as 50 times the telescope's aperture in inches. So, that means you can expect an 8-inch Schmidt-Cassegrain scope to give you a maximum usable magnification of 400x. But when, and where?

This number varies according to sky conditions. If the atmosphere is turbulent, you may not be able to use an eyepiece that gives 200x. On the best nights, however, an 8-inch scope may give fine views at 600x.

This is one instance when I like to quote Bill Murray's character in *Ghostbusters*: "It's more of a guideline than a rule." — **Michael E. Bakich,** Senior Editor

NO MOON WALTZ

Q: Why doesn't our solar system contain any moons orbiting a moon? — **Bob Kolbas,** Raleigh, North Carolina

A: It is difficult for moons in our solar system to retain their own satellites ("sub-moons") because moons orbit close

enough to their planets that the planets' gravitational influences are dominant. **If a sub-moon could form around (or be captured by) a satellite, the gravity from the parent planet would quickly destabilize the sub-moon's orbit, either ejecting it from the satellite system or sending it into orbit around the planet.**

Regular moons likely can't grow massive enough to allow them to retain a sub-moon. The gas giants' satellites formed in circumplanetary disks from the rock and ice material left over from the planets' formation, analogous to the creation of the planets from the material left over after the Sun formed. Consequently, these moons are much less massive than their host planets. For rocky planets, there may not have been enough material left over after planet formation for satellites to form nearby. Earth's Moon formed from the debris of an unlikely collision between a young Earth and a Mars-sized object, and Mars' moons are probably captured asteroids.

On the other hand, astronomers know of hierarchical star systems with bodies orbiting bodies orbiting bodies. For example, Nu (ν) Scorpii consists of seven stars, with the member stars paired off like dancers and orbiting other stellar couples. Arrangements as complex as Nu Scorpii are rare, however, even for stars, because small external perturbations can easily upset the delicate gravitational waltz, and most multiple star systems have only two or three members. — **Brian Jackson,** NASA's Goddard Space Flight Center, Greenbelt, Maryland

SPACE ASTROPHOTOGRAPHY

Q: Does the Hubble Space Telescope actually take a number of sub-exposures and then stack them? If so, how long are typical sub-frames? — **Jerry Wilson,** Goleta, California

A: To assemble deep-field surveys, astronomers take many separate exposures with the Hubble Space Telescope that range from about 10 to 30 minutes in duration. They take multiple exposures through different color filters, ranging from ultraviolet through visible to near-infrared radiation. Also, the telescope is slightly repositioned between some exposures to allow for image "dithering." Dithering means the telescope's pointing shifts slightly to put the target in different locations on the CCD detectors in separate exposures. Dithering improves image detail beyond what the pixels (picture elements) alone would deliver in one image. It also helps remove artifacts caused by seams between CCD chips and those caused when cosmic rays strike the detectors during each exposure.

Astronomers assemble all the images once received. They combine the separate exposures on a uniform grid of pixels. We call this process "drizzling." — **Ray Villard,** Space Telescope Science Institute, Baltimore, Maryland

To create this image of 30 Doradus, a star-forming region in the Large Magellanic Cloud, astronomers with the Hubble Space Telescope stacked exposures taken through different filters. The data depict light captured through ultraviolet to visible and Hydrogen-alpha filters. NASA/ESA/F. Paresce (INAF-IASF, Bologna, Italy)/R. O'Connell (University of Virginia, Charlottesville)/the Wide Field Camera 3 Science Oversight Committee

CHANGING CONSTANTS

Q: Have scientists thought of what type of universe would evolve if physical constants had different values? — **Jim Johnson,** Dallas, Texas

A: In recent years, developments in cosmology and string theory have led astrophysicists to consider the possibility that our universe is but one member of a huge ensemble of universes — a "multiverse." Some of these universes could have, in principle, constants of nature (like the strengths of the gravitational force, the electromagnetic force, and the strong nuclear force) that differ from those in our universe.

Detailed calculations have shown that for a relatively wide range in the values of the above three parameters, stars could still form. However, in a universe with much stronger gravity, there wouldn't be enough time for complexity (and life) to arise. Other calculations have considered universes with different values of the cosmological constant — the most likely candidate of the repulsive "dark energy," which cosmologists believe propels the acceleration of cosmic expansion. For sufficiently large values of the cosmological constant, no gravitationally bound systems (such as galaxies) can form.

Ideas about the multiverse are still highly speculative. In principle, not just values of the constants of nature could vary in other universes, but even the laws of physics themselves could change. — **Mario Livio,** Space Telescope Science Institute, Baltimore, Maryland

Find out the universe's size before and after inflation at www.Astronomy.com/toc.

Send your questions via e-mail to: **askastro@astronomy.com**; or write to **Ask Astro, P. O. Box 1612, Waukesha, WI 53187**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

Tour the Local Group of galaxies

Grab your telescope and look for these 16 often overlooked members of our galaxy's neighborhood. **by Tom Polakis**

M32 is a close companion to the Andromeda Galaxy. You can see this elliptical galaxy (also known as NGC 221) peeking out of massive Andromeda's dusty spiral arms. Wolfgang Promper

Eleven years after American astronomer Edwin Hubble provided empirical evidence from the nearby "nebulae" M31, M33, and NGC 6822 that galaxies exist outside our own, he pioneered their placement into groups and clusters. He named and defined the Local Group in his 1936 book, *The Realm of the Nebulae*, and also ascribed its first nine definitive members.

The Local Group center lies between the Milky Way and Andromeda galaxies — these massive galaxies also gravitationally dominate the group. The giant spirals' satellite galaxies and other nearby star cities populate a volume some 10 million light-years in diameter.

From our vantage point, Local Group members move through space independent of cosmic expansion; the local gravitational force beats out the universe's large-scale pull. Our neighborhood contains about 50 known members, but there may be as many as 80 galaxies, and astronomers keep turning up new suspects. Some are more familiar than others. Instead of observing M31, M33, and the Magellanic Clouds, let's begin with some lesser-known ellipticals and then move to irregular galaxies.

NGC 205 is a satellite of M31, but it's not nearly as close to its main galaxy as M32. At magnitude 8.9, this dwarf elliptical galaxy is the brightest Local Group member mentioned in this story. Anthony Ayiomamitis

Around town

The nearest companions to Andromeda (M31) are the elliptical galaxies **M32** (NGC 221) and **NGC 205**. Through a 10-inch telescope, M32 is bright with a blazing core but spans only 3' by 2' and lacks structure. Scan to the opposite side of the Andromeda Galaxy to find NGC 205, which you will quickly notice is larger and appears fainter. (However, its integrated magnitude is brighter.) My 13-inch scope shows a 9' by 5' halo that brightens gradually toward the center; a 1'-wide core is brighter still. A field of view greater than 3° nicely shows M31 and its two nearest satellites.

About 150,000 light-years separate NGC 205 and M31, which is similar to the distance between the Magellanic Clouds and the Milky Way. Only 20,000 light-years separate M31 and M32.

Pan 7° to the north of the Andromeda Galaxy to find another pair of its dwarf elliptical companions — **NGC 147** and **NGC 185**. My 4-inch telescope shows NGC 147 with some difficulty as 6' long and half as wide, exhibiting the slightest brightening toward the center. NGC 185 is more compact, but easier to see. A mid-sized scope (between 8 and 12 inches) at

Contributing Editor **Tom Polakis**, *an experienced observer, has written for* Astronomy *magazine for 2 decades.*

Bernhard Hubl

NGC 147 is another companion to Andromeda. Walter Baade confirmed this dwarf elliptical galaxy's membership in the Local Group in 1944.

Bernhard Hubl

NGC 185 is likely gravitationally bound to NGC 147. Only 58" separate the two dwarf elliptical galaxies.

magnifications greater than 200x begins to reveal this galaxy's brightest star clusters. Advanced deep-sky observers have successfully chased some of NGC 185's bright globular clusters, which are only barely non-stellar. Because NGC 147 and NGC 185 lie just 15° away from our own galaxy's plane, the field of view surrounding them is rich with stars.

Dwarf spheroidal galaxies, a specific type of elliptical, have masses similar to globular clusters but diameters thousands of times larger. They are the least luminous galaxies and therefore the most difficult to see with backyard telescopes. In the late 1930s, American astronomer Harlow Shapley discovered the **Fornax Dwarf** and the **Sculptor Dwarf**, the first two dwarf spheroidals. Although the Fornax Dwarf is less than one-quarter of the distance between us and M31, you'll need a dark sky and a good observing technique to detect it. Aperture does not rule in this case: Place more than 1° of field around the Fornax Dwarf, and then sweep your eye to see the galaxy's subtle haze. It will appear uniform in brightness and a bit less than ½° across.

Far easier to see than the galaxy itself is its globular cluster NGC 1049. My 4-inch turns up a non-stellar spot at just 100x. The Fornax Dwarf contains an additional half dozen globular clusters that are more challenging objects.

The Fornax Dwarf galaxy was discovered by Harlow Shapley in 1938. However, its brightest globular cluster (NGC 1049) had been spotted about 100 years prior. Jason Jennings

Once you spot the Fornax Dwarf, move about 20° to the west to locate the slightly fainter Sculptor. It is a bit larger and more diffuse than the Fornax Dwarf, presenting only a brightening of the field.

Situated about ⅓° due north of 1st-magnitude Regulus (Alpha [α] Leonis), the field of **Leo I** could not be any easier to locate. While it's an 11.2-magnitude elliptical galaxy, it is difficult to see due to glare from the bright foreground star. Move Regulus entirely out of the field of view to improve your odds of picking out Leo I. I found it to be 4' by 3', elongated east-west, and uniformly bright.

Resolving stars in external galaxies is always a thrill. My 18-inch telescope at 310x fleetingly shows a couple dozen of Leo I's brightest member stars.

Bernhard Hubl

Leo I is an 11th-magnitude dwarf elliptical. The bright star Regulus (Alpha [α] Leonis) makes seeing the galaxy to its north difficult. Try moving Regulus out of the field of view to spot the dwarf.

Move from Leo's head to its hindquarters to glimpse another distant Milky Way satellite, **Leo II**. It appears faint through a 13-inch telescope as 5' across with no central concentration. You'll find it 1.6° north of magnitude 2.6 Zosma (Delta [δ] Leonis).

The last two elliptical galaxies on our list are dwarf spheroidals — the **Ursa Minor Dwarf** and the **Draco Dwarf**

Leo II is a satellite galaxy to the Milky Way. This dwarf spheroidal sits about 750,000 light-years from our home galaxy's center. Chuck Kimball

Bernhard Hubl

The Ursa Minor Dwarf, one of the first dwarf spheroidal galaxies discovered, lies some 240,000 light-years from the Milky Way's center. Old stars seem to make up this satellite galaxy.

NGC 6822 contains an unusually high abundance of HII regions (areas of ionized gas surrounding young stars) for a dwarf irregular galaxy. These regions are the purple and pink bubbles scattered across the galaxy. Daniel Verschatse

The Draco Dwarf Galaxy holds the distinction as one of — if not the — most dark-matter dominated galaxies known. This Milky Way satellite galaxy sits about 290,000 light-years distant. Bernhard Hubl

(UGC 10822). These are "twin" galaxies, with similar distances, masses, and luminosities, showing little sign of interaction with other galaxies. Again, dark skies are a requirement for visual observers. The Ursa Minor Dwarf — an extremely faint galaxy about 20' in diameter — is centered on an 11th-magnitude star 4.7° south-southwest of magnitude 3.0 Pherkad (Gamma [γ] Ursae Minoris). Look for a gray shade slightly lighter than the sky with little definition at the edge.

The Draco Dwarf surrounds three stars arranged in an arc 3.4° west-southwest of magnitude 3.8 Xi (ξ) Draconis. Despite its cataloged brightness and size, it appears even fainter and smaller than the Ursa Minor Dwarf, but a 16-inch or larger telescope at high magnification will show its individual stars, which are as bright as 17th magnitude.

The unusual type

Many irregular galaxies contain HII regions (areas of ionized gas surrounding young stars) and star clouds that we also find in the Milky Way, which is why I find them more interesting than ellipticals. In 1884, Edward Emerson Barnard discovered **NGC 6822** in Sagittarius. Since then, astronomers have observed it often. Through a 10-inch telescope, it is a mostly uniform haze 9' long and half as wide. A faint bar runs along the galaxy's long axis. At higher magnifications still using this scope, NGC 6822 has a clumpy appearance. A nebula filter helps bring out two HII regions at the north end.

IC 10 is roughly 2.3 million light-years distant and obscured by the dust of our own Milky Way. It's still visible through a 10-inch scope as a 4' by 3' haze behind a splendidly rich field in Cassiopeia. Despite IC 10's faintness, it appears to hover among these stars, which adds a magnificent effect. Although it is situated almost 1 million light-years from M31, it is likely a satellite galaxy to Andromeda.

IC 1613 lies in a bland star field in northern Cetus. We use the term "nearby" to describe this galaxy — about 2.4 million light-years away — but it's all relative. At this distance, the limit of resolution for amateur telescopes is greater than the separation between the Sun and Sirius (about 8.6 light-years). Through a 13-inch telescope at 75x, I detected a uniform brightening of the sky similar to a faint comet about 15' in diameter. A nearby 7th-magnitude star does not do the low-contrast scene any favors.

A short pan into the western portion of Cetus the Whale brings in another

Visit some Local Group members

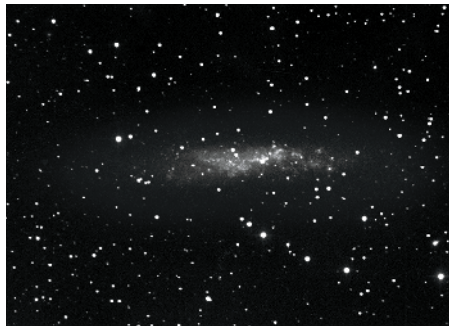
Name	Type	R.A.	Dec.	Const.	Size	Mag.
WLM	Irregular	0h02m	–15°28'	Cetus	12' by 4'	11.0
IC 10	Irregular	0h20m	59°18'	Cassiopeia	7' by 6'	10.3
NGC 147	Dwarf elliptical	0h33m	48°31'	Cassiopeia	13' by 8'	10.5
NGC 185	Dwarf elliptical	0h39m	48°20'	Cassiopeia	12' by 10'	10.1
NGC 205	Dwarf elliptical	0h40m	41°41'	Andromeda	22' by 11'	8.9
M32 (NGC 221)	Elliptical	0h43m	40°52'	Andromeda	9' by 7'	9.0
Sculptor Dwarf	Dwarf spheroidal	1h00m	–33°43'	Sculptor	40' by 31'	10.1
IC 1613	Irregular	1h05m	2°07'	Cetus	16' by 15'	9.9
Fornax Dwarf	Dwarf spheroidal	2h40m	–34°27'	Fornax	17' by 13'	9.3
NGC 3109	Irregular	10h03m	–26°10'	Hydra	19' by 4'	10.4
Leo I	Dwarf elliptical	10h08m	12°18'	Leo	10' by 7'	11.2
Leo II	Dwarf spheroidal	11h13m	22°09'	Leo	12' by 11'	12.6
GR 8	Irregular	12h59m	14°13'	Virgo	1' by 1'	14.7
Ursa Minor Dwarf	Dwarf spheroidal	15h09m	67°13'	Ursa Minor	30' by 19'	11.9
Draco Dwarf	Dwarf spheroidal	17h20m	57°55'	Draco	36' by 25'	10.9
NGC 6822	Irregular	19h45m	–14°47'	Sagittarius	16' by 14'	9.3

R.A.=Right ascension (2000.0); Dec.=Declination (2000.0); Const.=Constellation; Mag.=Visual magnitude

Local Group member IC 10 harbors star-forming regions. It's the closest starburst galaxy to us, at about 2.3 million light-years. Adam Block/NOAO/AURA/NSF

IC 1613 is an irregular galaxy about 2.4 million light-years away. It has so little dust that astronomers can see background galaxies through IC 1613. Bernhard Hubl

Irregular galaxy WLM was named for its discoverer (Wolf) and the two scientists who determined its nature (Lundmark and Melotte) 17 years later. Chris Schur



NGC 3109 sits at the outer reaches of the Local Group. Some astronomers question this irregular galaxy's membership because it's 4.2 million light-years distant. Martin Germano

isolated irregular galaxy, **WLM** (Wolf-Lundmark-Melotte). Despite its unconventional designation, this is a moderately easy target for backyard telescopes. It appears similar in size to NGC 6822 and only slightly fainter. Rather than a mere brightening of the sky, it has a well-defined edge. An early observation with my 13-inch telescope showed it as "uniform," but upping the aperture to 20 inches resolved several stars.

Just 2' west of WLM's center is WLM-1, a rarely observed 16th-magnitude globular cluster. Veteran deep-sky observer Steve Gottlieb was barely able to detect it in a 33-inch telescope.

NGC 3109 in Hydra is a long streak among these mostly round dwarf galaxies. With a 13-inch scope, I saw this 10.4-magnitude galaxy as 10' by 3', elongated east-west, and moderately faint. It is brighter on the west end, where a superposed 10th-magnitude star sits. NGC 3109 is clumpy in this brightest region. The east end is wider and more diffuse. This galaxy lies in a rich field not far from the Milky Way's plane.

Although the designation of **GR 8** might imply it's a "great" galaxy, it barely qualifies as "good" through the eyepiece. Gibson Reaves included this distant dwarf in his 1956 catalog. To find GR 8, it's best to begin with the bright Virgo cluster edge-on galaxy NGC 4866 and pan ¼° to the northwest. Here you might see a clumpy haze only 2' across that shows no central concentration. Some astronomers say that GR 8 is not a Local Group member because of its 6.6-million-light-year distance from our galaxy.

The Local Group holds some 40 more galaxies not listed on these pages. Over your observing evenings, challenge yourself to see as many members of our galactic neighborhood as possible.

Visit www.Astronomy.com/toc to locate each member of the Local Group.

10 things to do on a cloudy night

If the weather ruins your observing plans, you can still improve your techniques, re-evaluate your equipment, and prep for the next clear night.

by Michael E. Bakich

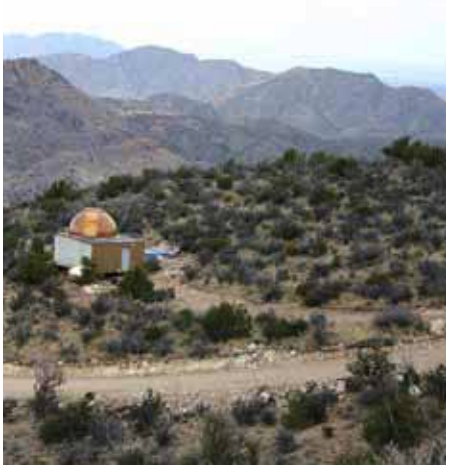
All readers can sympathize with someone who plans to observe on a certain night only to have clouds intervene. What then? Well, you can plop down on the couch and watch a DVD of last season's *Desperate Housewives*, or you can continue to think about astronomy. Here are 10 ideas that will occupy your time fruitfully.

1 Compile future observing lists

Planning on observing this weekend or during the next New Moon? The good news is that we know what will be in the sky. The bad news is that there are thousands of objects to choose from.

So, while you relax, plan ahead. You could pick a specific constellation and go after all of its deep-sky treasures within reach of your telescope. Be warned: If you choose a densely populated group like Sagittarius or Ursa Major, you're going to need a few extra nights.

Maybe your current interest is planetary nebulae. In specific-object cases, plan your observing run to start in the western sky (which disappears first), and work your way eastward.



Michael E. Bakich

Even the finest observing locations, like this one near Rancho Hidalgo Astronomy Village outside Animas, New Mexico, experience cloudy nights. You can turn such a minus into a plus by following one of the ideas in this story.

2 Review your last few observing sessions

In addition to looking forward, one profitable activity for a cloudy night is to look back and examine your last several outings. Few observers do this.

Ask yourself, "What went right?" (I don't mean just the weather.) Then ask yourself, "What went wrong?" I know it's a more difficult question, but be honest! Do you need a new observing partner? That may sound extreme, but it's something I've had to deal with in the past. It was a decision I did not make lightly, but I was sure happy after I made it.

Other questions you can ask yourself are: "Did I take the right equipment?" or "Am I trying to tackle too many objects in one night?" The latter question addresses a tough issue. With so many wonderful objects to view, what's the right amount of time to spend on each?

To me, every session is different. I've been just as happy observing nine objects on one night as I have observing 90 on another. And the equipment you use can vary from night to night. On one, I'll happily use a 3-inch refractor while on a different night only a 30-inch computer-controlled light bucket will do.

3 Inspect your observing kit

Checking your observing kit is something you won't have time for in the field, but deficiencies in what you bring will affect your observing. Perhaps you need to add a tool or two. Having pliers or a small set of hex wrenches may save a whole night.

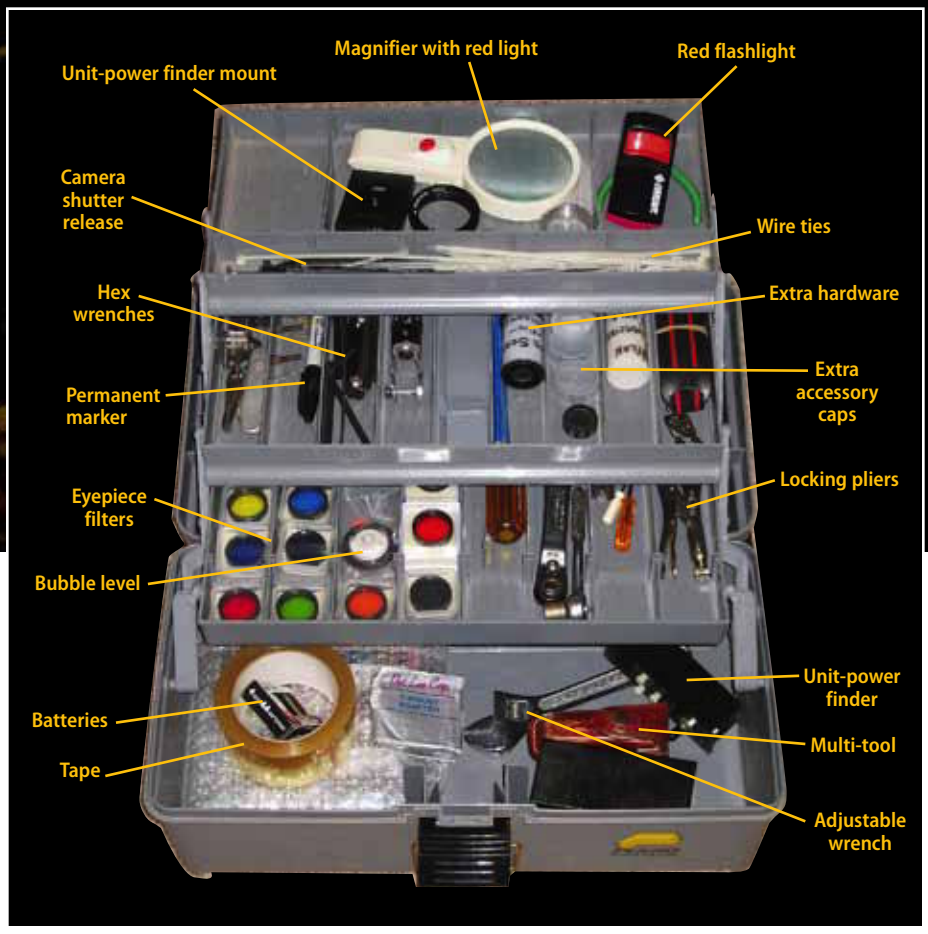
Conversely, are you toting items you never use? If one of your eyepieces gathers dust because you have a better one with the same focal length, maybe it's time for an eBay listing.

Don't overlook your observing chair, an accessory I value highly and one you'll spend lots of time in. Is it still comfortable? If not, does the seat just need more padding, or do you need a new chair?

4 Check "The Sky this Month" and other observing stories

Astronomy's staff produces each magazine so it appears a month in advance to give you plenty of time to plan for sky events. Use it! See what the planets are doing. Are any meteor showers, comets,

Michael E. Bakich *is an* Astronomy *senior editor who has logged thousands of clear nights and too many cloudy ones.*



Your observing kit should contain what you need for each session. This is my kit (a large fishing tackle box). It has enough space to let me include items I use only occasionally. I re-evaluate the contents about twice a year. I keep my eyepieces in a separate case. Michael E. Bakich

or asteroids in view? Then scan the rest of the issue for specific observing stories. This month, for example, those of you with large scopes can target Local Group galaxies (page 46).

5 Re-evaluate your observing site

You may have used the same dark-sky site for years, but things change. And — even above your choice of telescope — where you observe from is the most important decision you'll make. So, at least periodically, ask yourself if the site is too remote or not remote enough. How does the level of light pollution compare to when you first observed there? Also, is it safe? In case of a problem, do you have cell phone reception?

6 Clean or repair your equipment

The amount of dirt an observing case collects — be it a handcrafted wooden beauty or a plastic tackle box — astounds me. A cloudy night gives you the chance to clean it. Likewise, if you have an observatory, pick up anything lying around, and take care of things like hanging wires or leaks. Beyond repairs, this might be a good time to add a shelf or a storage cabinet.

7 Update your observing log

I strongly urge everyone to keep a log. The best observers I know do this for every session. A cloudy night is a good time to transcribe your last session(s) from your digital or tape recorder to a word-processing program. If you keep a pen-and-paper log, a night off will let you transcribe tape-recorded comments made while you were at the scope.

8 Learn the sky

Beginning stargazers will benefit immensely by opening a star atlas (or the "StarDome" at the center of this issue) and noting where constellations and bright stars are relative to one another. Start with any pattern you recognize outside. Dozens of objects are easy to locate near the Big Dipper, Orion, or the Summer Triangle. You'll be surprised at how much you'll remember the next time you're under the stars.

9 Get to know your new scope

The best time to assemble new equipment is before you take it observing, and a cloudy night gives you just that opportunity. If you don't fully assemble and test the fit of all parts and the telescope's drive, at least read the instruction manual, and lay your hands on every part it mentions. You'll thank me.

10 Dream big

In 1998, I was living in El Paso, Texas. On average, during some 20 nights, only one was cloudy. I remember thinking, "Well, at least I don't have to lug the scope out." The dichotomy of that thought hit me like a lead counterweight: On the one hand, I loved observing; on the other hand, it was a burden to set up every night.

For the next 3 hours, I sketched out what, about a month later, would become my backyard observatory. Your dream may differ. You may read all the ads this month and then decide to purchase your own observatory. Alternatively, you might plan an observing trip to a dark Southwestern site or to a star party. Whatever you dream of, just remember, cloudy nights can be good things — as long as they're rare.

July 11 eclipse

Darkness over Easter Island

All total solar eclipses are dramatic, but our setting for the July 11, 2010, event vaulted it to the top of the list. **by Michael E. Bakich**

The one thing those traveling to see a total solar eclipse don't want to hear is, "Sorry, folks, we won't see it today because of clouds." This was never more a concern than for July's eclipse in the Pacific Ocean. For years, potential viewers had pointed to this event because totality would occur over Rapa Nui, the native inhabitants' name for Easter Island.

But would it be clear? To answer that question, meteorologists combed through weather data, and trip leaders headed to Easter Island a year early to gauge the weather. In the end, the prospects stood at 50–50. Nature would flip a coin: If it came up heads, our group would observe totality among the Moai — the island's massive sculptures. If tails, well, at least we'd see Easter Island.

The adventure begins

Astronomical Tours, located in Warrensburg, Missouri, provided the tour for our group of 40. The trip through Bolivia, Chile, and Easter Island was superb. My wife, Holley, and I were the leaders, but the real hero was our Bolivian guide, Ivan Blanco, who met us at the La Paz airport and traveled with us throughout the trip. Blanco has been a tour guide for 28 years, and it showed.

While in Bolivia, we stayed at the Inca Utama Hotel, which stands on the shore of Lake Titicaca, some 16° south of the equator. Because of the efforts of one of Astronomical Tours' founders, the late Vic Winter, the resort features a 22-inch Starmaster Dobsonian-mounted reflector in a roll-off roof observatory.

During the four nights we were at the hotel, our group enjoyed views of southern wonders like globular cluster Omega Centauri (NGC 5139), the Eta Carinae Nebula (NGC 3372), Centaurus A (NGC 5128), and many deep-sky objects in Scorpius and Sagittarius that stood higher in the sky than from the United States. We also had many high-quality wide-field views thanks to fellow traveler Darren Trizzino, who brought his Takahashi FSQ-106 refractor.

Next stop: Chile

On July 7, our group spent nearly the entire day on buses. From the hotel, we headed into El Alto, a suburb of La Paz, then took a right turn onto the main road to Chile. We soon found ourselves in the wilderness of the Altiplano — Bolivia's high plains. Nearby, we could see the extinct volcano Nevado Sajama, the country's highest mountain. Its snow-capped peak rises 21,463 feet (6,542 meters) above sea level.

The Chilean border crossing was eventless, and soon we were driving beside Lake Chungará, one of South America's highest lakes. That night, we stayed in the small mining town of Putre.

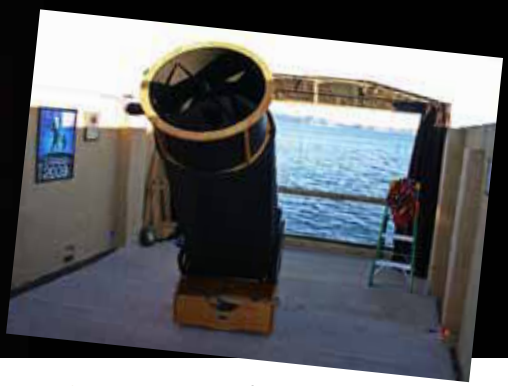
The next day, we took a route similar to the Inca Trail around the Andes Mountains. At one time, this system comprised 25,000 miles (40,000 kilometers) of trails. We made several stops, but in early afternoon we reached the Atacama Desert — the driest place on Earth.

The Astronomical Tours group explored Easter Island for 5 days. At Ahu Tongariki, the largest stone platform and one that carries 15 Moai, I suggested we take a group photo. The largest Moai weighs 86 tons and is the most massive ever erected on Easter Island. Michael E. Bakich

Darren and Julia Trizzino stand atop a tiny section of the more than 40,000-square-mile (105,000 square km) Atacama Desert in Chile, the driest location on Earth. Michael E. Bakich

Caroline and Bernard Vroom sit beneath snow-capped Nevado Sajama, Bolivia's highest mountain, during our group's bus ride through the Andes Mountains heading toward Chile. Michael E. Bakich

◀ **The solar corona** appeared finely structured, although not as bright as during recent eclipses. To the eye, the Sun had the appearance of a thick letter X. Mike Reynolds



A 22-inch Starmaster reflector stands ready at the Inca Utama Hotel in Bolivia. Through it, group members observed southern deep-sky objects. The hotel stands on the shore of Lake Titicaca, which is visible through the observatory's window. Michael E. Bakich

Some weather stations there have never recorded rainfall. As an astronomer, I couldn't help but compare the landscape to that of the Moon. We drove for many miles and saw no life. Indeed, for many in our group (including me) this was one of the highlights of the trip.

Another Chilean highlight was our stop at the Museo San Miguel de Azapa. Inside, we viewed the famous Chinchorro mummies. The remains are the world's oldest, predating the ones in Egypt by several thousand years. A dimly lit room in a new wing of the museum holds rows of mummies in small boxes lined up on gurneys. Here was where the real research occurred. My wife likened it to a scene from *The X-Files*.

Easter Island at last

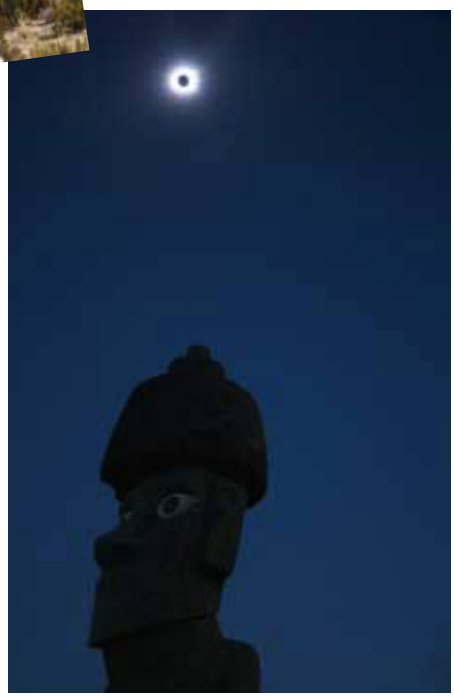
We reached our eclipse-viewing destination around noon July 10 — the day before totality. It was pouring. That afternoon, we toured the site where we would watch the eclipse. It was still raining, and the trails looked like mudslides. In the evening, a bunch of us went out for dinner. More rain, but the food was great.

Bad weather, but I had a smile on my face because one of our group members was Dutch meteorologist Henricus (Harry) Otten, who had been providing forecasts for eclipse day. At T-minus 10 days, prospects were not good. As we got closer to the event, however, the data Otten was using showed a good possibility — above 80 percent — that we would, indeed, see the eclipse. And we did.

By first contact (the start of the eclipse), which occurred around 12:40 P.M. local time, a few clouds lingered, but none that interfered with our viewing. The 4 minutes and 39 seconds of totality began a little after 2 P.M. and was fabulous. At second contact (the start of totality), the diamond ring blazed brilliantly.

During totality, I rated the corona (the Sun's outer atmosphere) as quiet, meaning its extent wasn't as great as those of recent eclipses. It had a distinctive X shape, and its filaments appeared well-defined. In the darkness, Venus and Mercury were easy to spot. In addition, I saw Sirius, Canopus, and Alpha Centauri, the sky's three brightest stars, among others.

But the view that will stay with me for the rest of my life occurred halfway through totality. I had been concentrating on the Sun's prominences and corona, the visible planets and stars, and the horizon sunset effect. With 2 minutes to go, however, I widened my gaze. That's when my eyes beheld the Sun standing 40° up in the sky above seven of Easter Island's iconic Moai. It was the view that I'd been thinking about for more than a decade, and here I was. I'll see other eclipses — many, I hope — but no Earth-sky combination will ever compare with that.



The eclipsed Sun stands over a Moai (stone sculpture) at the Easter Island site of Tahai. Our group of 40 intrepid eclipse-chasers joined about 600 others at this exotic location to witness the celestial lineup of the Sun, the Moon, and Earth. George Willis

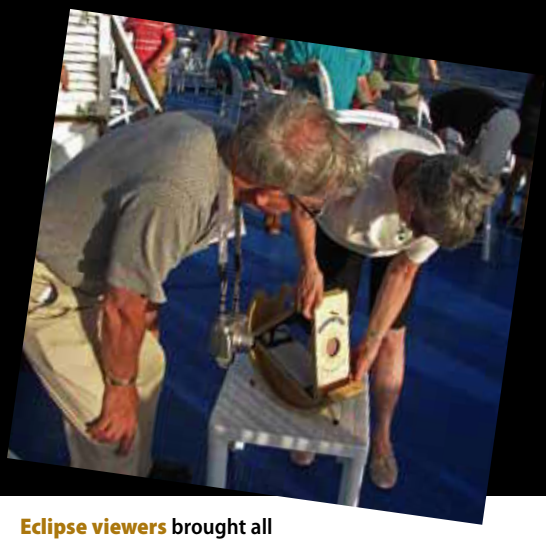
The amazing Chinchorro mummies reside at the Museo San Miguel de Azapa in Chile. These remains, which predate the better-known Egyptian mummies by two millennia, are among the country's top archeological wonders. Michael E. Bakich

Michael E. Bakich, *a senior editor of* Astronomy, *has led 12 expeditions to total eclipses.*

Totality washes over the South Seas

A cruise through French Polynesia proved the perfect prelude to July's total solar eclipse.

by Richard Talcott



Eclipse viewers brought all sorts of equipment to watch and record the Moon's progress across the Sun's face. Evelyn Talcott

People who have never seen a total solar eclipse often ask me why I travel halfway around the world for a few minutes in the Moon's shadow. Part of the answer is that those few minutes are unlike anything else you can experience on this planet. The other part: Those precious moments represent only a small piece of the whole adventure. Who would turn down 2 weeks in French Polynesia wrapped around a total eclipse?

Melita Thorpe of MWT Associates organized *Astronomy* magazine's tour to view the July 11 eclipse. Most of the 60 people in our group arrived in Papeete, Tahiti, late the evening of June 28. After a few fitful hours of sleep, we were up for a quick breakfast and a short ride to Papeete harbor. There, we boarded the *Aranui 3*, which would be our floating home for the next 2 weeks. The ship holds nearly 200 passengers, and ours was the largest group on board.

The *Aranui 3* is more than a cruise ship — it's also a freighter that carries 2,000 tons of cargo to the Marquesas Islands. It serves as the major lifeline for this part of French Polynesia, which lies approximately 900 miles (1,500 kilometers) northeast of Tahiti.

At each stop along the way, the passengers would disembark for an island tour while the crew unloaded gasoline, building materials, livestock, food, beverages, and most anything else you could imagine for the local population. At the end of the day, the workers had refilled the *Aranui 3*'s hold with island produce.

It took many of us a day or two to get our "sea legs" — to convince our brains that the constant up-and-down and sideways motion was normal. But once we did, we were ready for everything the islands had to offer.

Senior Editor **Richard Talcott** *has now witnessed nine total solar eclipses, and hopes to see many more.*

Island adventures

We docked at six islands in the Marquesas: Fatu Hiva, Hiva Oa, Nuku Hiva, Tahuata, Ua Huka, and Ua Pou. At most stops, local dancers and musicians greeted the passengers. The Polynesians know how to entertain, and they don't get many opportunities to perform for outsiders except for when the ship comes to town.

All the Marquesas formed when magma erupted through the seafloor and thrust volcanoes above the ocean's surface. Although these volcanoes are long extinct, the islands' rugged landscapes endure. When the warm, muggy Pacific air meets the islands, the air rises and forms clouds that typically cloak the mountain peaks. Meanwhile, the coasts and beaches remain generally sunny.

Passengers on the *Aranui 3* prepare to get off the barges at the dock on Hiva Oa, while the ship waits in the background to deliver its cargo. Evelyn Talcott

▲ **A pair of tikis** stand watch on Hiva Oa. The foreground tiki stands 8 feet (2.4 meters) tall and represents a powerful chief. The one in the background likely depicts the chief's wife. Evelyn Talcott

◀ **Tropical fruit trees,** like this banana tree with its flower, dot the landscapes of the Marquesas Islands. Richard Talcott

The sky at totality from the *Aranui 3* had more clouds than we might have preferred, but fortunately none obscured the Sun. Richard Talcott

The diamond ring at third contact lasted for several seconds, marking a stunning conclusion to more than 4 minutes of totality. Bob Bedell

More often than not, the nights were clear. And on two evenings, captain Jean Paul turned off the ship's lights so we could experience the southern sky. The heart of the Milky Way in Sagittarius and Scorpius passed overhead during the evening hours, giving us views of these constellations and our galaxy's central bulge that few of us who live at mid-northern latitudes ever experience.

But the real excitement lay with the constellations farther south. Centaurus and its two luminaries, Alpha and Beta Centauri, stood out. Even Omega Centauri (NGC 5139), the brightest globular cluster in the sky, was easy to see with naked eyes. But the true gem of the evening sky had to be the smallest constellation of all: Crux the Southern Cross. These sights, along with a plethora of often-overlooked southern constellations such as Circinus, Corona Australis, Lupus, and Triangulum Australe, kept us satisfied well into the night.

A date with darkness

We bade the Marquesas goodbye July 8 and set sail for the island chain to their south, the Tuamotu Archipelago, where we would view the eclipse. The Tuamotus are coral atolls. They formed in fire like the Marquesas, but the volcanic islands eventually subsided beneath the ocean and left behind turquoise lagoons surrounded by barrier reefs.

Our destination was Hikueru, a 6-by-9 mile (10-by-15 km) oval atoll near the center line of the July 11 eclipse. But by late in the day July 10, the weather over Hikueru looked less than promising. Based on the latest forecasts and satellite images, the captain steered us toward a spot some 21 miles (34 km) southeast of Hikueru. We weren't entirely free of clouds there, but it looked like a spot that would give us a good chance to see totality.

◀ **This sign** on Fatu Hiva warns the locals to wear eclipse glasses if they want to view the solar eclipse. Evelyn Talcott

◀ **A woman makes a headdress** from flowers on Makemo Island in the Tuamotus. The ship stopped here July 10, a day before the eclipse. Evelyn Talcott

As the passengers were busy setting up cameras and other equipment, first contact arrived at 7:23 A.M. under a clear sky. So far, so good. But as the Moon's black disk swallowed the Sun over the next 75 minutes, intermittent clouds caused more than a little anxiety. Minutes before totality began at 8:38 A.M., a thin, high-level cloud moved across the Sun. We weren't sure whether to panic or to enjoy the rainbow of colors filtering through the cloud.

We did the latter, and with good reason — the cloud quickly moved away and left us with a spectacular diamond ring followed by 4 minutes and 14 seconds of totality. For those of us who tore our eyes away from the beautiful corona, the sky appeared strikingly dark with little twilight color and about a half dozen planets and bright stars visible.

By the next day, many in our group were heading back home. As we waited at the airport in Papeete, conversations invariably turned to plans for the next total eclipse. Unfortunately, the wait will be a long one. The Moon's dark shadow won't touch Earth again until November 13, 2012, when northern Australia and the South Pacific will be the prime observing sites. I hope to see you there.

See more of Easter Island and French Polynesia at www.Astronomy.com/toc.

Astronomy mythbusters

You shouldn't believe everything you see or hear relating to astronomy. Except what you read here, of course. **by Richard Talcott**

Have you heard that the world will end in 2012, or that NASA faked the Moon landings? So have the editors at *Astronomy* magazine — more times than we can count. To limit our aggravation down the road, we decided to gather 10 common myths concerning astronomy and put them to rest.

The Red Planet
NASA/J. Bell (Cornell)/ M. Wolff (SSI)

Myth #1: Mars will look as big as the Full Moon on [fill in the date].

Not gonna happen — and never will. This myth started with an e-mail that appeared before Mars made a close approach to Earth in 2003. On August 27 of that year, the Red Planet was closer than it had been in nearly 60,000 years. Its proximity meant that it appeared larger through a telescope than it had in recorded history, some 25.1" across.

But a Full Moon, on average, appears 31.1' across — about 75 times larger. The original e-mail stated that, through a telescope at a magnification of 75x, Mars would appear as big as a Full Moon does to the naked eye. That statement is true as far as it goes. Unfortunately, the bit about the telescope and magnification didn't make it into most retellings.

Even stranger, this e-mail keeps going and going like the Energizer Bunny. Even now, your inbox may contain a message about how Mars soon will be as big as the Full Moon, even though the planet is but a shadow of what it was in 2003.

Myth #2: The world will end December 21, 2012.

This myth serves as a cautionary tale about not believing everything you read (*Astronomy* magazine excepted). This one is just the latest in a long line of end-of-the-world scenarios, many of which incorporate astronomical events. The

Mayan observatory Michael E. Bakich

specific date arises from the ancient Mayan calendar. One of this civilization's so-called "long counts" ends with the 2012 winter solstice (on December 21). Believing this myth requires a lot of faith in the Mayans' ability to predict the future.

True believers have developed a number of possible astronomical causes of the 2012 calamity. My two favorites: The impending collision of the planet "Nibiru," which the Sumerians supposedly discovered and orbits the Sun every 3,600 years (it doesn't exist); and the alignment of the Sun with our galaxy's center (the alignment occurs every year, not just in 2012).

Myth #3: The Moon has a dark side.

Two-faced Moon
David Jenkins

This myth is true, just not in the way you might think. Many people believe the Moon's farside is perpetually dark. That's true only at Full Moon, however. At New Moon, bright sunlight bathes the entire farside.

Half of the Moon is always dark, just as half of Earth is (it goes by the name "night"). On Earth, night lasts about 12 hours, on average. On the Moon, it takes 14.8 days from sunset to sunrise. But just as on Earth, every place outside the polar regions experiences both day and night.

Myth #4: There is no gravity in space.

In the 17th century, British physicist Isaac Newton developed the law of universal gravitation. The key word here is *universal*. According to Newton, and to basically all scientists since, every object in the universe attracts every other object with a force proportional to the two bodies' masses and inversely proportional to the square of the distance between them. This law holds for all objects — those in space as well as on Earth.

So how did this myth arise? Blame the Space Age. Everyone could see weightless astronauts floating about in (or just outside) their vehicles. Sci-fi author Arthur C. Clarke came up with a term for this: "zero G." Sure sounds like a lack of gravity.

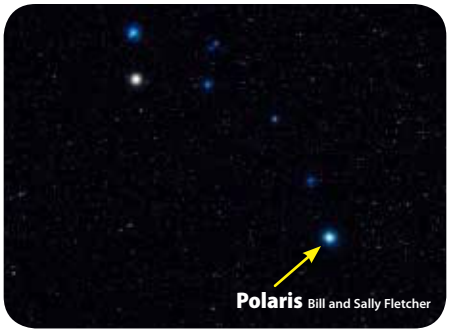
But the truth is that gravity pulls these astronauts toward Earth with nearly the same force as when they were on the ground. It's just that Earth pulls on the orbiting spacecraft and everything in it with an equal force. If there were no gravity in space, the astronauts and spacecraft would fly away in a straight line, not be bound to Earth.

Ed White space walk (1965) NASA

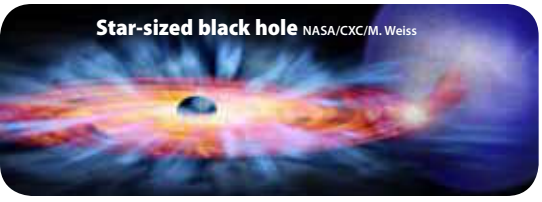
Myth #5: Polaris is the brightest star in the night sky.

This one's not even close to true. Polaris, better known as the North Star, barely cracks the top 50. The night sky's brightest star, Sirius, shines 25 times brighter.

The myth likely arose because Polaris' historical importance far outshines its brightness. This star lies near the North Celestial Pole (the spot toward which Earth's axis points), so it stays fixed in the sky throughout the night and from year to year. Navigators of yore used its constancy to fix their position at sea, vital information when sailing into the great unknown.



Polaris Bill and Sally Fletcher



Star-sized black hole NASA/CXC/M. Weiss

Myth #6: A black hole's gravity will suck in everything in its vicinity.

Black holes have a bad rep, but, in many ways, they are pussycats. What would happen to Earth if the Sun suddenly turned into a black hole with an equal mass? Nothing. Well, it would get awfully cold and dark, but our planet's orbit would remain unaffected.

From a distance, a black hole's gravitational pull behaves like that of any object with the same mass. A black hole is special because it packs its mass in such a small volume — a black hole of 1 solar mass would have a diameter of 3.7 miles (5.9 km). The black hole's voracious appetite becomes noticeable only when you get near the beast. Then you can worry about its gravity.

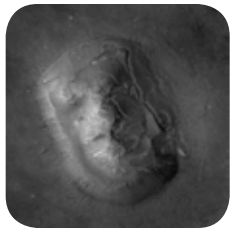
Richard Talcott *is an* Astronomy *senior editor and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*

Cerro Tololo NOAO/AURA/NSF

Myth #7: Astronomers build observatories on mountaintops to be closer to the stars.

Do the math: The nearest star beyond the Sun, Proxima Centauri, lies 4.22 light-years from Earth. That's 24.8 trillion miles (39.9 trillion kilometers) away. So, climbing a mountain to get a few miles or kilometers closer wouldn't help at all.

Astronomers head to mountains for a variety of reasons. First, it raises them above part of Earth's atmosphere, and turbulence there distorts the view through any telescope. Second, it raises them above most of Earth's water vapor, which allows them to see infrared radiation from the cosmos. And third, isolated mountain peaks lie far from light pollution, yielding better views of the universe.



Face on Mars NASA/JPL/MSSS

Myth #8: Martians carved the "face" on Mars.

Martians appear to be a hardy bunch. After the hoopla generated by 19th-century sightings of "canals" on the Red Planet's surface, grand hypotheses about a dying civilization prospered. These beings couldn't survive the first spacecraft images of Mars, which showed a cratered and uninhabited world. Not to fear: A picture snapped in 1976 by NASA's Viking 1 orbiter showed what looked like a face on the planet's surface. Suddenly, talk of alien civilizations building monuments akin to the Egyptian pyramids flourished among many non-scientists.

Alas, it is not so. The "face" is actually a mesa nearly 2 miles (3 km) across that looks like a human face only under certain lighting conditions. Sharper photos from more-recent spacecraft show the mesa in all its glory, but without signs of intelligent construction.

Earth in winter NASA

Myth #9: Earth's seasons occur because of our changing distance from the Sun.

This myth sounds logical. It even would be true if Earth's axis were perpendicular to its orbit around the Sun. But our planet's axis tilts 23.4° from perpendicular, so the Sun's altitude varies during the year. When the Sun beats down from nearly overhead, we get summer. Winter arrives when the Sun arcs low across the sky.

All you need to know is that Earth lies closest to the Sun in January and farthest away in July. That's exactly opposite of how it would be if distance caused the Northern Hemisphere's seasons.

Buzz Aldrin on the Moon (1969) NASA

Myth #10: NASA faked the Moon landings.

Will this one ever die? Conspiracy theorists have built an industry that rivals the Hollywood special-effects labs where these landings supposedly were faked. (Don't bother telling these people that the image-rendering computers and powerful animation software now used routinely didn't exist 40 years ago.)

The conspiracy would have to cover 35,000 NASA employees, 200,000 contractor employees, thousands of scientists who examined the Moon rocks, and a host of others. And if the landings were faked, how can you explain (rationally, I mean) the retroreflectors left behind, off of which scientists continue to bounce laser beams, and the images of equipment on the lunar surface returned recently by the Lunar Reconnaissance Orbiter?

To see more myths debunked, visit www.Astronomy.com/myths.

Orion's wide-field imaging dream scope

With this 8-inch f/4 astrograph, you can produce superb deep-sky images. **by Chris Schur**

In the past decade, astrophotography has changed radically. The renaissance in this field is due to the widespread use of digital imaging, including affordable charge-coupled device (CCD) and digital single-lens reflex (DSLR) cameras. In the past few years, a mismatch has developed between these modern imaging devices and telescopes designed primarily for visual use. Such instruments are either too slow optically, too expensive, or lack the precision necessary for sharp images of celestial portraits.

Recently, Orion Telescopes and Binoculars introduced a high-speed imaging telescope — the 8-inch f/4.0 Newtonian Astrograph Reflector — at the almost unbelievable price of $449.95. Would this potentially groundbreaking instrument live up to its billing? I decided to put it to the test and find out.

Chris Schur *is an astroimager who lives in Payson, Arizona. He has contributed images to* Astronomy *for several decades.*

Technical details

Most experienced astroimagers would agree that a fast, large-aperture instrument with a moderate focal length is best for general imaging of deep-sky objects. An inexpensive, high-quality optical system that is daringly fast would ideally suit today's sophisticated cameras. Such a scope would need to produce a high level of sharpness and also be easy to use.

In January, the astrograph arrived from Orion Telescopes. Unpacking the telescope was a pleasant surprise when I discovered the box contained a lot more than just the optical tube assembly. The black glossy finish on the 16-pound (7.3 kilograms) tube is simply breathtaking.

Equally stunning is the superb machining on the focuser, a dual-speed 2" Crayford-style unit. It comes black-anodized with a white scale silk-screened on the drawtube. It also has finely finished knobs and 10-to-1 speed reduction for the fine-focuser. The rigid focuser displays excellent craftsmanship.

The straight-through 8x50mm finder scope also is of high quality. It mounts via a machined dovetail slot on the tube for an easy and quick disconnect. Two black tube mounting rings come with the scope, and each has a variety of ¼" mounting holes on its base.

More nice surprises include the tool-free collimation knobs in two colors for easy identification under low light levels, and a full-aperture front cover for the optical tube assembly. Orion also designed a small cooling fan mounted on the back of the mirror cell. This nice accessory has a plug for an external battery pack, which Orion provides.

The package includes a 1¼" optical peep sight for coarse collimation, a light

Chris Schur

The Pleiades (M45) in Taurus is a favorite target of astroimagers. The author combined ten 5-minute exposures through the Orion 8-inch Astrograph to bring out the gas in the area of the star cluster.

Product specifications

Orion 8" f/4.0 Newtonian Astrograph Reflector
Aperture: 8 inches
Focal length: 800mm
Focal ratio: f/4.0
Length: 27.5 inches (70 cm)
Weight: 16 pounds (7.3 kg)
Includes: 2" dual-speed Crayford-style focuser, 8x50mm finder scope, tube rings, cooling accelerator fan
Price: $449.95

Orion's 8-inch f/4.0 Newtonian Astrograph Reflector is a telescope the company designed specifically for astroimagers. *Astronomy*: James Forbes

The primary mirror cell of Orion's astrograph features a cooling fan and six collimation knobs (three adjusting and three locking). *Astronomy*: James Forbes

version of *Starry Night* software, and a printed manual. A bonus is the beautifully machined 2" extension tube complete with a black-anodized 1¼" adapter for visual use. This compensates for the extended photographic back focus Orion had to build into the optical design.

And speaking of optics, the company coated the BK-7 glass primary and secondary mirrors with aluminum having a reflectance of 91 percent. What more could an astroimager ask for?

Methodology

For my evaluation of this instrument, I mounted it on a homemade cradle on an Astro-Physics AP1200 mount in my northern Arizona observatory. A stout set of mounting rings on the top of the cradle carried a 90mm refractor guide scope. For imaging, I used a Hutech-modified Canon XTi DSLR with a Baader Multi-Purpose Coma Corrector.

I used a small laptop computer running *Images Plus* software for extremely accurate focusing of the camera. I sequenced the many exposures I took with a Canon remote timer. To guide the setup, I used a Meade DSI III Pro CCD camera with my laptop running *PHD Guiding*. Controlling the focus and tracking with the laptop computer ensured consistent, repeatable testing of this instrument, critical for an accurate evaluation.

See more of Schur's images through this scope at www.Astronomy.com/toc.

Your next telescope?

I found this telescope a total pleasure to use. The precise mechanical operation of its focuser made all the difference in the world. Sharp arcsecond-sized star images filled the field of view on successive 5-minute exposures with an absolutely stunning amount of nebulosity visible on my DSLR's screen.

A comparison of images of a dense Milky Way star field with and without the Baader coma corrector revealed that — even without the additional optical correction — the instrument performed well with small CCD chips (those that did not exceed about half the size of a DSLR frame). For larger chips, like those in DSLRs, I recommend the coma corrector, which produced sharp, full-frame images with pinpoint stars right to the corners.

Orion's 8-inch f/4.0 Newtonian Astrograph Reflector allows budget-minded sky shooters access to a new level of high-quality imaging. The combination of large aperture, blazing speed, and crisp resolution makes it a scope to consider for wide-field imaging.

Contact information

Orion Telescopes and Binoculars
89 Hangar Way
Watsonville, California 95076
[t] 800.447.1001
[w] www.oriontelescopes.com

The Jellyfish Nebula (IC 433) in Gemini resulted from a star exploding several thousand years ago. The author captured this deep-sky object by stacking seventeen 5-minute exposures taken through Orion's 8-inch f/4.0 Newtonian Astrograph Reflector. Chris Schur

by David H. Levy

Nature reaches for the stars

A rare bloom grows ever higher and closer to the skies.

In the Sonoran Desert in Arizona, even the plants entreat us to look to the stars. Earlier this year, about the time a survey team I was in discovered its first CCD comet (a faint 19th-magnitude speck named Jarnac), my *agave americana* plant began to produce a stalk.

I first noticed its skinny peak as it nudged above the tall surrounding leaves. With each passing day, it grew several inches, climbing and climbing until now it soars dozens of feet above the ground, always striving for the boundless heavens. It's a thrill to pass it each night, its sheer size always a pleasure to behold.

On this particular agave hangs a tale that ties it specifically to astronomy. When my wife, Wendee, and I got together in 1996, we bought a home in Vail, Arizona, with an expanse of desert lying to the south, giving us plenty of room for an observatory. About a third of the way from the back door to the observatory entrance stood the young agave, which the home's previous owners had recently planted.

Its long, narrow green leaves gathered into a bunch and pointed toward the sky. The leaves have sharp points that discourage touching; if broken, their toxic sap can severely irritate human skin.

Agave plants are common in southern Arizona, and they dot the landscape. They are also known as "century plants" because, supposedly, they flower by growing a tall stalk only after a century-long life; after the flowering, the plant dies. Recently, I've heard that the agave actually produces its stalk much sooner, between 10 and 15 years.

Our agave now has a stalk more than 50 feet (15 meters) high and about 8 inches (20 centimeters) thick near its base. With spring's strong winds, I thought it might blow over, but it is so firmly rooted that gusts up to 40 mph (64 km/h) haven't given it any trouble.

Our particular agave has lasted about 13 years and seen some of the higher and lower points of my comet-hunting career. When we first met in 1996, I had gone more than 2 years without finding any new comets; when those 2 years stretched into a dozen, I pretty much gave up expecting to find any more.

But still, whether I went outdoors in shirtsleeves or in a heavy winter coat, I always kept up my search because it had become such a fun habit. The long dry spell finally broke in October 2006 with my visual discovery of Comet P/2006 T1 north of Saturn.

It seemed oddly appropriate, then, that when the faint light of 19th-magnitude Jarnac found its way into one of our electronic cameras in March, our agave was about to take its final stand. Although the stalk's triggering mechanism is still somewhat mysterious, last summer's lack of rain, or this winter's good rains, might have had an effect; the comet's presence, though, seems as good a trigger as any.

Although it sounds like a joke, connecting it to the cosmos actually adds a fresh perspective to our desert nights, as a flowering desert plant can imitate the enormous clouds of gas and dust between the stars in our galaxy.

For a few weeks, our clear nights will be enhanced because of this tall, skinny stalk dominating our south yard. Then it will start to die, leaving several healthy offspring to continue the show. Although our yard is a circus of cactus and other remarkable plants, the agave is the leading light of this season, and its stalk is another reminder of the area's precious night sky.

Whenever Wendee or I exit from one of our south-facing doors at night, the first thing we see is a dark starry sky. The second thing we see is this darkened stalk towering above our yard, as if it wants to touch the stars all by itself. It's just one more reminder that in the desert, everything — even our little agave — feels the pull of the night sky.

The author's *agave americana* grows steadily taller in front of his observatory in these before and after pictures, taken just a few weeks apart. Wendee Levy

Browse the "Evening Stars" archive at www.Astronomy.com/Levy.

by Glenn Chaple

Teeing up to the sky

With so many scopes on the market, selecting the one that best fits your needs can be a challenge.

A 6-inch f/8 Dobsonian-mounted reflector, like this Orion SkyQuest XT6i Computerized IntelliScope, is a good all-purpose telescope for deep-sky and planetary observing.
Orion Telescopes & Binoculars

Imagine playing a round of golf with just one club. A driver would work well off the tee, but it wouldn't be much help on the green. A putter is the club of choice there, but it would fare poorly on tee shots. Success on the links comes from having a full set of clubs, each serving a particular function.

It's the same in astronomy. No single telescope does it all. At one end of the spectrum are telescopes that provide low-power, wide-field views of extended deep-sky objects like clusters and nebulae. At the other end are scopes that deliver the high magnifications needed to discern planetary detail, split close double stars, or observe compact deep-sky objects.

Generally speaking, a telescope's focal ratio provides a clue as to whether it's better suited for extended deep-sky or lunar and planetary observing. You can find the f/ratio by dividing the focal length of a telescope's objective lens or mirror by its diameter (aperture). A reflecting telescope with a 60-inch (1,500mm) focal length and 12-inch (300 millimeters) mirror has an f/ratio of 5 to 1 (notated f/5).

With so many telescopes available on the market, selecting the one that best fits your observing needs might seem pretty daunting. Knowing a telescope's f/ratio will help. Here's a summary of the astronomical "golf clubs" available.

Short-focus telescopes

Scopes with f/ratios of f/4 or f/5 fall into two major groups — reflectors or refractors with apertures no greater than 6 inches (known as rich-field telescopes, or RFTs) and large-aperture telescopes (usually Dobsonian-mounted reflectors bigger than 10 inches). Because they afford a generally wide field of view, short-focus telescopes are the instruments of choice for anyone interested in viewing large objects.

Browse the "Observing Basics" archive at www.Astronomy.com/Chaple.

RFTs afford spectacular low-power, wide-field views of extended sky objects like the Pleiades (M45), the Andromeda Galaxy (M31), or the Orion Nebula (M42). They serve a function similar to binoculars, but with greater magnifications — typically 20x and up. Like binoculars, these telescopes are compact in size, making them excellent travel scopes.

If you really want to go deep, you'll need heavy artillery. Here's where a Dob with an aperture greater than 10 inches comes in. These "light buckets" feast on Messier and NGC objects. Don't let the short f/ratios fool you. With its long overall focal length, a large Dob can achieve high magnifications — sufficient for lunar and planetary work, although you'll need a shorter focal length eyepiece than you would in a high f/ratio scope.

Long-focus telescopes

A century ago, refracting telescopes with f/ratios as high as f/15 were the mainstay of backyard astronomy. Back then, the sky objects of choice were the Moon, planets, and double stars — celestial targets that mandated the high magnifications a long-focus refractor can deliver.

Except for the commonly sold 60mm f/11 model, today's refractors rarely come in f/ratios that large. To get a high-power instrument with a focal length greater than f/10, you'll need to look into a catadioptric telescope.

The most common catadioptric designs are the Schmidt-Cassegrain (SCT) and the Maksutov-Cassegrain. While the typical commercially produced SCT has an f/10 focal ratio, the Mak-Cas often features f/ratios around f/12. These long focal ratios allow for the high magnification and sharpness needed to tease out lunar and planetary detail and resolve close multiple star systems. Catadioptric telescopes also perform well on compact deep-space objects like planetary nebulae.

All-purpose telescopes

Is there a middle-ground telescope that works equally well on deep-space and solar system targets — an all-purpose astronomical "golf club" with an f/ratio between f/6 and f/9? At the risk of narrowing the field too much, I recommend a 6-inch f/8 Dobsonian-mounted reflector.

Such a telescope is relatively inexpensive, portable, and easy to handle, which makes it a clear-cut choice for budding backyard astronomers. Moreover, its ability to capture both deep-space and solar system objects affords novices the opportunity to sample a variety of night sky offerings. Later in their observing adventures, newcomers can decide whether to purchase a short-focus scope for deep-space or one with a high focal ratio for lunar and planetary work.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com. Next month: the first Messier object, the Crab Nebula (M1). Clear skies!

by Tony Hallas

The secret to "stretching" data

Your astroimages will reveal more detail after you apply a few simple techniques.

You've been shooting through a telescope with a CCD camera attached to it, collecting data, for some time now. Let's say your target was Bode's Galaxy (M81), and now you're ready to process the images. You want to show the faint outer arms and not burn up the nucleus, but how do you accomplish this?

The first step is to reduce the data by applying dark frames and flat fields. I explained how to do this in my September column. Next, combine these files into master 16-bit TIFF files with one of the popular image-processing programs like *MaxIm DL* or *CCDStack*.

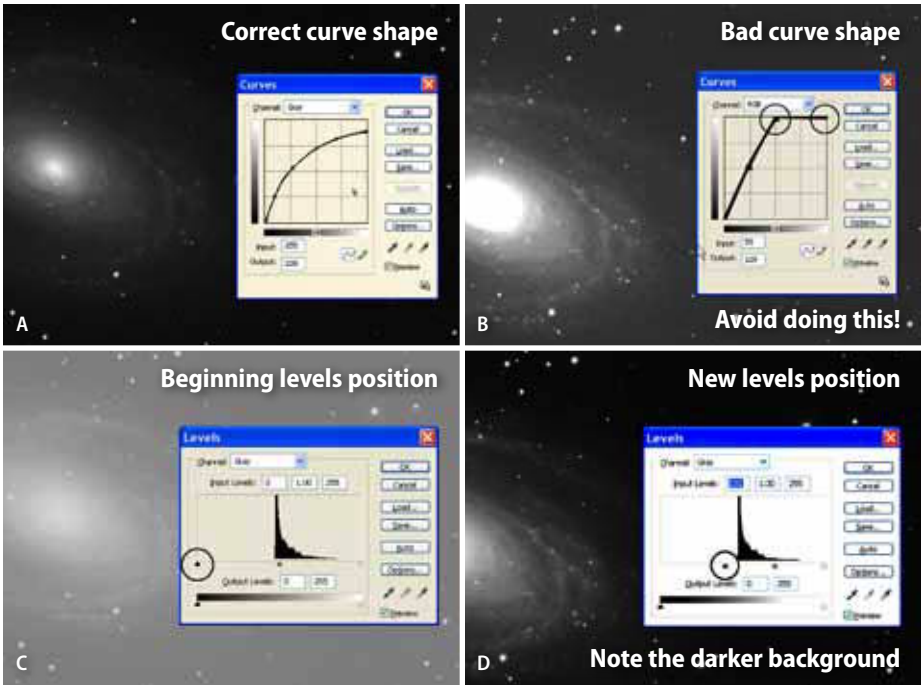
Once you create the master files, import them into Adobe *Photoshop*. (If you don't know how to use *Photoshop*, I recommend *Adobe Photoshop CS Classroom in a Book* by Adobe Press to get you started. You can find it and updates on Amazon.com and from other booksellers.)

Specifically, you will use *Photoshop*'s "curves" function. Curves allow you to "stretch" the data without losing any of it. They let you dig out all the faint detail while, at the same time, keeping your bright areas from washing out.

Let's first work on the luminance image. Follow these six steps:

1 Open the 16-bit master luminance TIFF file in *Photoshop*. It will appear dark with a few stars visible. The reason is because an astroimage without stretching has only a fraction of the data collected in a typical "daytime" exposure.

2 Open "curves." Make sure the shadows (not the highlights) are represented in the lower left-hand corner, and pull up the curve line as shown in illustration A. Using curves is simple. Pulling up on the curve lightens the image; pulling down darkens it. Furthermore, the curve is a representation of all the tonal values in your image, so where you pull on the curve relates to a specific density in your image.



Tony Hallas

The author created these Adobe *Photoshop*® screenshots with images behind them to illustrate points he makes throughout the text in this column. To stretch your images properly, be sure your *Photoshop* "Curves" and "Levels" boxes resemble the ones shown in illustrations A and D.

3 Follow just a few rules when working with curves: When stretching the curve, never let the curve touch the top of the graph. Also, always bring the curve's upper end point down slightly. See illustration B for what not to do.

4 After you have pulled up on the curve for the first time, and made sure the curve generally matches illustration A, click "OK." Your image just got lighter. Now repeat the process and the image will get lighter again. By doing this, you stretch the data without throwing any of it away, which sometimes happens when using image-processing automatic functions.

5 Keep repeating this process until the overall image appears too light. When you get to this stage of the process, reset the black point to make your image look normal again. The easiest way to do this is to open up "levels" and pull the black-point slider to the right until it is just a little bit outside the beginning of the graph. Although the image darkened, you keep all the detail already produced by the previous stretching. Click "OK" to accept the results. Illustrations C and D show the "before" and "after" of the black point position.

6 Now stretch the image again using curves until it becomes too light overall once more. Then reset the black point using levels. At some point in this process, M81's nucleus will become too light.

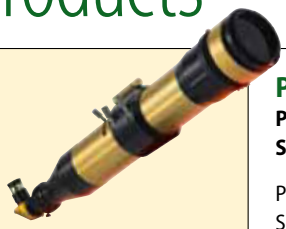
I'll stop here and continue this lesson next month when I'll show you how to selectively bring the galaxy's nucleus back under control.

Browse the "Imaging the cosmos" archive at www.Astronomy.com/Hallas.

New Products

Solar telescope

Meade Instruments
Irvine, California



Meade's SolarMax II 60mm Hydrogen-alpha telescope offers 0.7 angstrom bandpass. The company's RichView tuning method lets you tune the etalon on either side of the central wavelength. The unit comes with a Cemax eyepiece, a Sol Ranger finder, and a carry case.

Price: $1,299
[t] 800.626.3233
[w] www.meade.com

Padded telescope cases

Pacific Design
Santa Cruz, California

Pacific Design has new Soft Cases for Celestron 14 and Mewlon 250 telescopes. The Soft Case features heavy, water-resistant 1000 denier Cordura nylon and 210 denier lining. The case has 1 inch (25 millimeters) of foam padding on the bottom, and ⅜ inch (9.5mm) on the sides.

Price: $285
[t] 831.435.3880
[w] www.casesandcovers.com

Focuser-to-telescope adapter

Starlight Instruments
Columbia City, Indiana

Starlight Instruments' Custom Tube Adapter attaches the company's Feather Touch 3" Focuser (FTF3015B-A with 1.5" of drawtube travel) to the AstroTech 10-inch Ritchey-Chrétien telescope. The adapter is black-anodized aluminum.

Price: $164
[t] 260.244.0020
[w] www.starlightinstruments.com

Lightweight focuser

Starlight Instruments
Columbia City, Indiana

Starlight Instruments' Feather Touch lightweight focuser accepts 2" eyepieces and has 1.5 inches (38mm) of travel. The unit features a brake and a compression ring. The focuser weighs 0.875 pound (0.4 kilogram) and can lift and hold 8 pounds (3.6 kg).

Price: $409
[t] 260.244.0020
[w] www.starlightinstruments.com

Laser collimator

HOTECH
Rancho Cucamonga, California

HOTECH's Advanced CT Laser Collimator simulates the light path from a star to let users collimate their telescopes indoors or out. This model is for compound scopes with primary mirrors greater than 7.2 inches (183mm) in diameter.

Price: $455
[t] 909.987.8828
[w] www.hotechusa.com

German equatorial go-to mount

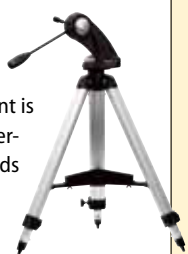
iOptron
Woburn, Massachusetts

iOptron's iEQ45 GoTo German Equatorial Mount weighs 25 pounds (11.3 kg) and carries a 45-pound (20.4 kg) payload. It comes with a polar scope, a built-in bubble level, a 32-channel GPS, periodic error correction, and a stainless steel tripod.

Price: $1,599
[t] 866.399.4587
[w] www.ioptron.com

Alt-azimuth mount

Orion Telescopes and Binoculars
Watsonville, California

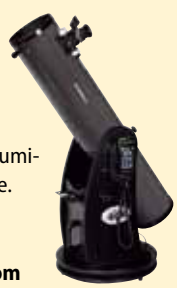


Orion's VersaGo II Altazimuth Mount is for telescopes up to 6 inches in aperture. The mount can carry 15 pounds (6.8 kg). Its head features a dovetail saddle. The mount length is 41.5 inches (1.05 meters) retracted and 63 inches (1.6m) extended.

Price: $194.95
[t] 800.447.1001
[w] www.orientelescopes.com

Go-to Dobsonian-mounted scope

Orion Telescopes and Binoculars
Watsonville, California



Orion's SkyQuest XT8g GoTo Dobsonian has 42,000 objects in its database. The unit includes a dual-speed 2" Crayford focuser, a 28mm 2" DeepView eyepiece, and an illuminated crosshair Plössl eyepiece.

Price: $849.95
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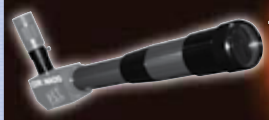

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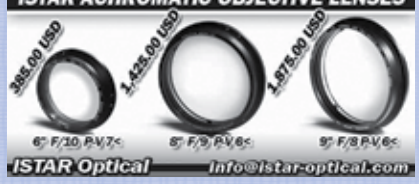

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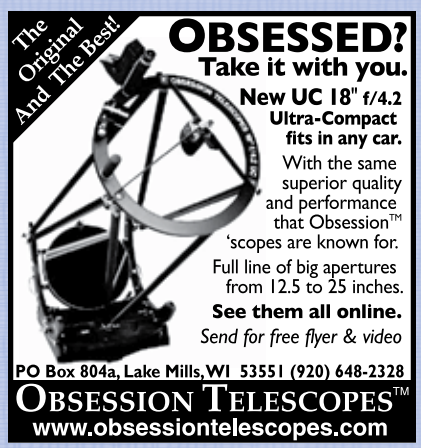
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The Cosmic Grid

All things high, low, weird, and wonderful in astronomy and space science. **by Bill Andrews**

WEIRD

HOT

NOT

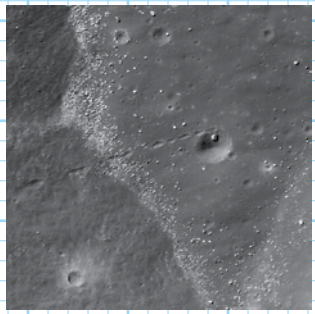
PREDICTABLE

Teleportation information
Using "quantum entanglement," scientists successfully teleport information about 10 miles (16 kilometers). Fans of science fiction, of course, stopped listening after hearing "successfully teleport."

High flying plans
Private company Bigelow Aerospace plans to launch inflatable habitats and space stations, making kids everywhere drool over the possibilities for a literal Moon Bounce.

More PC for NASA
The NAACP calls a Hallmark card that mentions "black holes" racist, a bad omen given astronomers' callous "dwarf" and "giant" remarks.

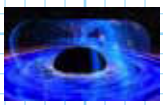
Western lights?
JPL scientists create an artificial aurora to better understand and predict space weather. Ah, the beauty and majesty of man-made nature.



Lunar landslide
An LRO photo shows a large boulder's path and eventual crash into a crater. Looks like Indiana Jones finally visited the Temple of Moon.

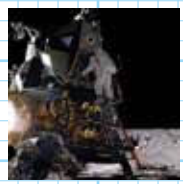
Super science seventh graders
A class of California seventh graders discovers a cave on Mars after studying photographs from the Odyssey orbiter. Apparently, the seventh-grade curriculum has moved on from my days of "the water cycle" and "the metric system."

Royal sendoff
Queen Beatrix of the Netherlands officially launches LOFAR, the world's largest radio telescope. And people think royalty are merely figureheads these days!

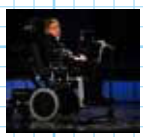


Back in black holes
Chinese researchers create an artificial mini "black hole" out of rings of metamaterials. Hippie astronomers scoff, preferring organic mini black holes.

Out-there art
The PBS show *History Detectives* alleges the Apollo 12 astronauts left a tiny ceramic chip with six etchings by famous artists aboard the lunar lander, making it almost certainly the most exclusive art house ever.

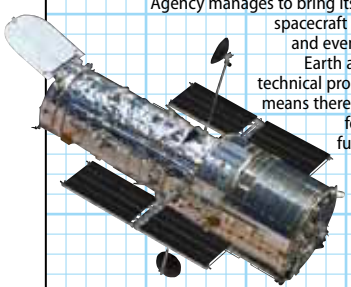


A case of spaceface
NASA invites the public to "Fly your face in space" by sending a digital picture aboard one of the last two shuttle missions. Unless something changes soon, it'll be the last chance for any part of you to fly on a space shuttle.



Science v. religion
Stephen Hawking tells ABC News' Diane Sawyer "science will win" over religion. [Punch line removed at the behest of the Letters editor.]

Brought back
The Japan Aerospace Exploration Agency manages to bring its Hayabusa spacecraft back to life and even land it on Earth after severe technical problems. This means there's still hope for Hubble's future, right?



Voice of a god
Morgan Freeman hosts and narrates a new show about space exploration for the Science Channel, *Through the Wormhole*. At last, a worthy successor to Carl Sagan's voice has been found!

Spaceship disappoints
A UFO recently spotted over Australia was probably just a rocket, quashing the notion that aliens might also enjoy surfing and exploring the outback.

Biological bias
Research on Canada's Lost Hammer Spring leads one expert to say life could survive on present-day Mars, causing a small frenzy. You know, guys, there are other reasons Mars is interesting besides potential life …

O comet! My comet!
Texas astronomers identify the "strange huge meteor-procession" Walt Whitman wrote about in his poem "Year of Meteors." As September's "Evening stars" showed, they should've just asked Dr. Levy-Shakespeare.

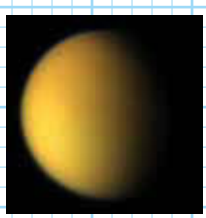
e-NASA
NASA releases a computer program that "enables students to launch [a] virtual space shuttle." Well, I guess virtual is better than nothing.

Rocket hurrah
SpaceX successfully launches its Falcon 9 rocket, indicating perhaps that rumors of American space flight's death have been greatly exaggerated.

Space lofts with air locks
NASA challenges college students to design, manufacture, and assemble an inflatable loft for NASA's future infrastructure. Let's hope they don't mind cookie crumbs and pizza stains on a few of those submissions.

Spitzer's stylings
JPL sends out a press release headlined " 'This planet tastes funny,' according to Spitzer telescope." Oh, so now everyone's a comedian.

Titanic developments
NASA's Chris McKay explains that several recent Cassini discoveries on Titan are only consistent with possible life, not indications of any sort, again proving that real life is not the movies.



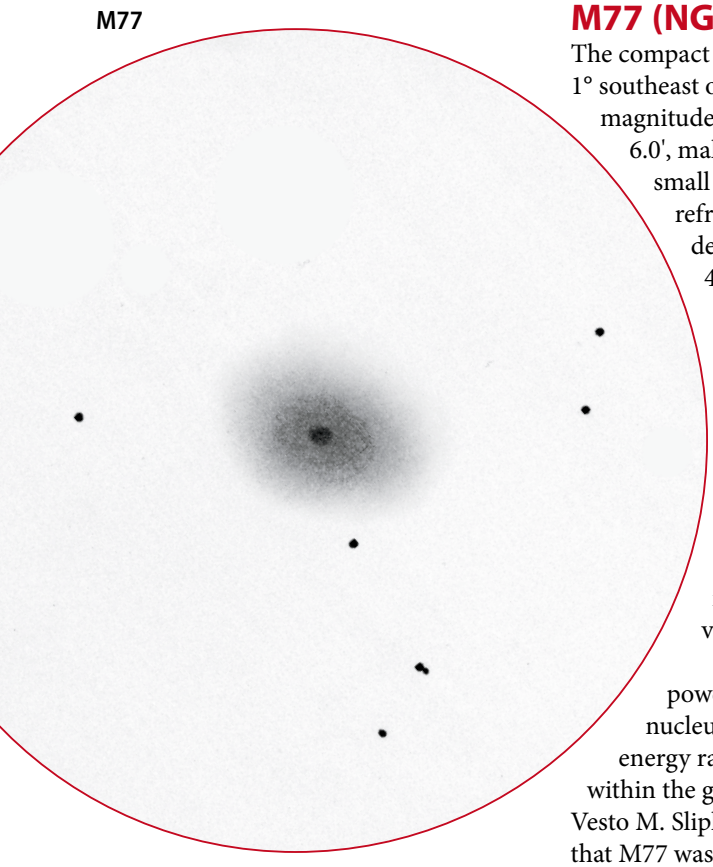
PHOTOGRAPHS: Nicolle Rager Fuller, National Science Foundation (Teleportation information); NASA (High flying plans); Netherlands Institute for Radio Astronomy (Royal sendoff); NASA/JPL-Caltech/ASU (Super science seventh graders); NASA/Kim Shiflet (A case of spaceface); NASA (Western lights?); NASA/Goddard Space Flight Center/Arizona State University (Lunar landslide); XMM-Newton/ESA/NASA (Back in black holes); NASA/Charles "Pete" Conrad (Out-there art); NASA/Paul Alers (Science v. religion); © 2010 Jupiterimages Corporation (Spaceship disappoints); NASA/The Hubble Heritage Team (STScI/AURA) (Biological bias); NASA (Spitzer's stylings); NASA/JPL/Space Science Institute (Titanic developments); George C. Cox (O comet! My comet!); David Sifry (Voice of a god); Lewis Center for Educational Research/Greg Waskul (e-NASA); SpaceX/Chris Thompson (Rocket Hurrah); NASA (Brought back)

Deep-sky Showcase

Astronomy's *editor sketches two of his favorite objects.* **by David J. Eicher**

M77 and NGC 1073

M77



M77 sketched by David J. Eicher using an 8-inch f/10 SCT at 70x.

M77 (NGC 1068)

The compact galaxy M77 — found about 1° southeast of Delta (δ) Ceti — shines at magnitude 8.9 and measures 7.1' by 6.0', making it an easy target for small telescopes. In a 2.4-inch refractor, it appears as a condensed ball of fuzzy light. A 4-inch scope at high power shows a clearly defined circular disk as well as a much dimmer outer halo of nebulosity. M77 is a Seyfert galaxy, one of the curious systems discovered by the American astronomer Carl Seyfert and cataloged for their intense and variable ultraviolet emission.

A 10-inch scope at high power shows a tiny, bright nucleus — the source of the high-energy radiation — embedded within the galaxy's center. In 1913, Vesto M. Slipher was the first to detect that M77 was one of two galaxies in which there are large redshifts. The other galaxy was the Sombrero Galaxy (M104).

M77

Ken Crawford

Designations: M77, NGC 1068
Position: 2h43m, –0°01' (2000.0)
Constellation: Cetus
Magnitude: 8.9
Size: 7.1' by 6.0'
Distance: 40 million light-years

NGC 1073

Adam Block/Mount Lemmon SkyCenter/ University of Arizona

Designation: NGC 1073
Position: 2h44m, 1°23' (2000.0)
Constellation: Cetus
Magnitude: 11.5
Size: 4.9' by 4.5'
Distance: 50 million light-years

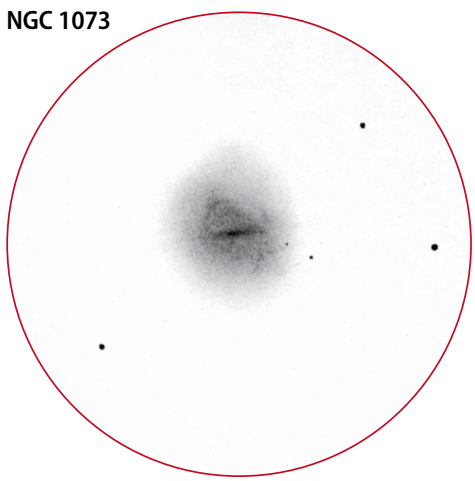
NGC 1073

M77 contains a few galaxies in a group. One outlying member of this group is NGC 1073, which shines at magnitude 11.5 but has a low surface brightness because its light is spread over a circular area 4' across. Photographs of this galaxy show unusual knotty structures in the arms; with the aid of a nebular filter, a large telescope may just be capable of revealing some of this detail.

Most telescopes show NGC 1073 as a large glow with a slightly brighter middle and little definition.

David J. Eicher *is the editor of* Astronomy. *He has observed and sketched deep-sky objects for 34 years.*

NGC 1073



NGC 1073 sketched by David J. Eicher using an 8-inch f/10 SCT at 70x.

reader gallery

Watch the space bubble

RCW 58 lies in the southern constellation Carina the Keel. This dim shell of gas forms a ring around the Wolf-Rayet star HD 96548 (also known as WR 40). Wolf-Rayet stars are hot (25,000 to 50,000 kelvins), massive (more than 20 solar masses), and near the end of their lives. The expanding bubble results from the central star ejecting stellar matter outward at high velocity and following it with a stellar wind that clears out the region surrounding the star. Astronomers note this nebula is remarkable for its large-scale curls and the existence of radial features not observed in any similar object.

RCW 58 (LightBuckets online telescope rentals 16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, Apogee Alta U9000 CCD camera, 90-minute exposures through red, green, and blue filters) • Jason Jennings, Melbourne, Australia

▶ **This full-disk solar image** shows numerous small filaments and prominences. The photographer combined nine exposures made from movie files to create this composite. (4-inch Vixen FL-102S refractor, SolarScope SF-70 0.7-angstrom Hydrogen-alpha filter, Lumenera SKYnyx 2–0M CCD camera, taken June 15, 2010, at 11h52m UT, from Selsey, England) • Pete Lawrence, Selsey, England

Barnard 164 is a dark nebula in Cygnus. Its discoverer, astronomer Edward Emerson Barnard, noted its V shape, which reminded him of a kidney. (6.4-inch Astro-Physics StarFire EDF refractor at f/7.5, SBIG ST-2000XM CCD camera, LRGB image with 48 minutes of exposure through each filter) • Anthony Ayiomamitis, Athens, Greece

Galaxy cluster Abell 262 is a loose group of more than 100 galaxies in Andromeda. The brightest member is the magnitude 11.9 elliptical galaxy NGC 708. (16-inch RC Optical Systems Ritchey-Chrétien reflector at f/9, SBIG STL-6303E CCD camera, 520 minutes of luminance data combined with 380 minutes of data through R, G, and B filters) • Mark Manner, Nunnelly, Tennessee

▶ **The Box** is a group of four galaxies — NGC 4169, NGC 4173, NGC 4174, and NGC 4175 — in Coma Berenices. The quartet spans about 5'. (24-inch RC Optical Systems Ritchey-Chrétien reflector at f/9, SBIG STL-11000 CCD camera, LRGB image with exposures of 120, 40, 30, and 40 minutes, respectively) • Adam Block, Mount Lemmon SkyCenter, University of Arizona

The Cat's Paw Nebula (NGC 6334, right) lies near the Lobster Nebula (NGC 6357) in Scorpius. British astronomer Sir John Herschel discovered both objects in 1837 while he was at the Cape of Good Hope in South Africa. (4-inch FSQ-106 ED apochromatic refractor at f/5, SBIG STL-11000M CCD camera, Hydrogen-alpha/LRGB image with exposures of 120, 45, 15, 15, and 15 minutes, respectively) • John A. Davis, Dallas, Texas

reader gallery

Send your images to: *Astronomy* Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, and exposure information. Submit images by e-mail to readergallery@Astronomy.com.

Taurus the Bull is a Northern Hemisphere constellation of autumn and winter. Its brightest star, yellowish Aldebaran (Alpha [α] Tauri), marks the Bull's eye. To the right of center lies the sky's brightest open cluster, the Pleiades (M45). At the right edge, the California Nebula (NGC 1499) glows in Perseus. (Guided exposure with a special filter that slightly diffuses the bright star images) • Bill and Sally Fletcher, Little River, California

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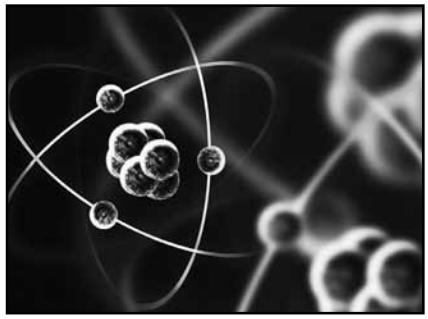

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Professor Benjamin Schumacher is Professor of Physics at Kenyon College. In 2002, he won the Quantum Communication award, the premier international prize in the field of quantum mechanics.

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